THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. V.

No. II.—FEBRUARY, 1918.

ORIGINAL ARTICLES.

I.—Eocystis, I. *Eocystites primævus* Hartt.

By F. A. Bather, M.A., D.Sc., F.R.S.

(PLATE V.)

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THE second edition of J. W. Dawson's *Acadian Geology* (1868) contains some notes communicated by C. F. Hartt. One of these, on p. 643, runs as follows:—

"*Eocystites primævus*, Billings, Coll. Hartt (Fig. 220). The little plate with radiating sculpture, represented somewhat enlarged in the figure, is regarded by Mr. Billings, to whom the specimens have been submitted, as indicating a new genus of Cystideans."

In this perfunctory manner, without diagnosis or description, was the genus *Eocystites* founded. Since a named species was mentioned, that species, *E. primævus*, must be taken as genotype, and the generic name is thereby validated.

Eocystites primævus again depends solely on the accompanying figure 220 (our Plate V, Fig. 1). Slight though this may appear, it does represent a plate of peculiar and recognizable shape. The holotype, which was said to be in Hartt's collection, was one of a series of specimens from the "Primordial Group" of St. John, New Brunswick, a group since referred to the Lower Cambrian. The specific name therefore may be accepted, and unless the plate can be shown to belong to some previously described genus and species, we must regard *Eocystites primævus* as representing an actual independent zoological entity.

It so happens that Dr. G. F. Matthew, of St. John, New Brunswick, formed the opinion that the plates known as *Eocystites primævus* were more properly referable to *Trochocystis*. He did not publish a definite statement to that effect, but he twice suggested or recorded the existence of *Trochocystis* in Canada, namely, in 1896, "Faunas of the *Paradoxides*-Beds in Eastern N. America" (Trans. New York Acad. Sci., xv, p. 207), and in 1899, "The Cambrian System in the Kennebecasis Valley" (Trans. Roy. Soc. Canada, ser. II, vol. iv, sect. 4, p. 128). This latter refers to "a single discoid plate" in Division 1 *b* of the Cambrian at Long Island, Kennebecasis Bay, Nova Scotia.

It was when I asked Dr. Matthew for the evidence on which he recorded this Central European genus from the other side of the Atlantic that he replied (in litt., February 5, 1900): "I may say that the evidence is not direct. *Eocystites* is founded on single star-shaped plates. With these occur a few elongated plates somewhat rectangular. The greater abundance of the star-like plates led me to infer the probable presence of some such genus as *Trochocystites*, as the form to which the two kinds of plates belong."

The name *Trochocystites* first appeared in print in 1859 (J. Barrande, Bull. Soc. Géol. France, ser. II, vol. xvi, p. 543), but then only as a *nomen nudum*, and without a species. In 1860 De Verneuil & Barrande (ser. cit., vol. xvii, p. 537) published a description, and took as genotype the Bohemian species *T. bohemicus* Barrande, of which no other description had till then been published. The fossil from north of Sabero, Léon, Spain, which they figured (pl. viii, figs. 1, 1*a*), was referred to that species "avec réserve"; it most probably belongs to *T. barrandei* Mun.-Chalmas & Bergeron.

If, then, Dr. Matthew's opinion is well founded there would follow the unfortunate result that *Trochocystis* (*-ites*), as the name of a genus with a clearly understood genotype, would have to yield to **Eocystis* (*-ites*), based on a species that depends in its turn on a single obscure plate. It is therefore advisable to subject *Eocystites primævus* to more critical examination than it has yet received.

There are, of course, more important reasons for undertaking such an inquiry. Plates from the Cambrian rocks of widely separated parts of the world have been referred to *Eocystis*, and the name has also been doubtfully applied to a fairly well-preserved fossil cystid retaining its brachioles—*E.* (?) *longidactylus* Walcott (1886).

That I have been able to make this study is due to the kindness of Dr. G. F. Matthew, who sent me forty specimens referred by him to *E. primævus*, and considered by him to afford the most complete representation of that species. Eleven of these have, through the generosity of Dr. Matthew, been retained for the British Museum, and registered E 7602–7612.

The specimens are labelled "Lower Cambrian, Division 1, C, 2, Paradoxides-beds; St. John, N.B.", except three, said to come from "Ratcliff's Millstream".

The matrix of all is a hard irregularly fissile shale, varying in colour from dark grey to olive green, and weathering brown. The substance of the fossils is either much decayed or entirely dissolved away, and the moulds or impressions are often stained with iron oxide. The shale has been subjected to some lateral pressure, so that in several cases the impressions are distorted.

The impressions referred by Dr. Matthew to *E. primævus* are divisible into four groups; the numbers of the British Museum representatives are quoted, as well as the letters which I attached to Dr. Matthew's specimens.

1. Stellate plates, the typical *Eocystites primævus*, E 7602–5, E 7611–12; G. F. M. *a*, *b*, *e*, *f*.

2. Plates with marginal pores. E 7608; G. F. M. *c*.

3. Columnals. E 7605–7, E 7602; G. F. M. *d*, *g*.

4. Undetermined plates. E 7609–10; G. F. M. *h*.

There seem no *à priori* grounds for supposing that all these specimens belong to the same species, or even genus. Nor is there any external evidence that they do not. They lie close together on the same surfaces of shale; at the same time they are never in any natural juxtaposition, but always occur as isolated plates or ossicles.

These four sets will therefore be described separately.

1. The Stellate Plates are probably to be regarded as thecal plates of a Pelmatozoan, and since a parallel is to be found only among Cystidea we may regard the Pelmatozoan as a Cystid.

Each plate has a small, but usually distinct, central umbo, from which folds radiate to the periphery. The ridges due to these folds on the outer surface of the plate are more marked than the corresponding furrows on the inner side of the plate (Figs. 7, 10, 11, 12). The number of folds varies from five to perhaps as many as seventeen (Fig. 6). In many instances three folds, arranged in Y fashion, are more prominent than the others, and merge into the umbo. Two folds nearly as pronounced are often seen to approach, or perhaps join, the umbo, one on each side of the Y and at about right angles to its stem. Thus arise five main folds, which, it will be noted, are not of necessity pentamerously symmetrical. The remaining folds do not reach the umbo, but while a few come rather near to it the rest are mere gofferings of the margin of the plate. Thus the total number of folds tends to increase with the size of the plate.

These folds present two points of difference from the folds and ridges so common on the thecal plates of many Cystidea and Crinoidea. First, the rare specimens in which the margin of the plate is indicated (G. F. M. *a*, *b*) appear to show that the main folds were directed towards the angles of the plate, whereas the axial folds of Crinoids and the rhomb-folds of Cystids normally pass across the sides of the plates, the more prominent among them bisecting the sides at right angles. Secondly, whereas the minor ridges of Cystidea Rhombifera and of all Crinoidea except *Porocrinus* are parallel to the major axial folds, thus giving rise to the characteristic rhomb-structure, the folds of *Eocystis primæva* radiate from the umbo like the spokes of a wheel. It follows from this that in two adjacent plates of *E. primæva* the folds cannot have passed in a straight line from one plate to another. It also seems probable that the plates cannot have fitted very accurately together, and that, if in any case two ridges of adjoining stellate plates did lie in the same straight line, then there must have been smaller irregular plates filling up the interspaces. A similar, though more definite and regular arrangement of folds is seen in *Amygdalocystis florealis*; but the plates of *Macrocystella mariæ*, which, as they lie in their matrix of Shineton Shale, are strongly reminiscent of *Eocystis primæva*, may be distinguished by the axial nature of the folding.

Since not a single stellate plate in Dr. Matthew's collection preserves a complete outline the exact measurements cannot be given. The long diameter varies from 2·5 mm. to 6 mm., but perfect specimens may have exceeded this. In the majority of

specimens, as preserved, it is about 5 mm. The plates appear to have been very thin, but thickened at the umbo and folds.

Some recent private correspondence suggests the need for an explanation that, in using the term folds, I have never meant to imply that a plate was subjected to any force which threw it into folds. The stereom was, one presumes, deposited in that shape from the outset. But it followed the course and structure of the stroma, and this was usually affected by mechanical stresses.

It is quite easy to see how under these conditions there arose the hexagonal plating, with folds at right angles to the sutures, common in normal many-plated Cystids (e.g. *Heliocrinus*, *Aristocystis*, *Echinosphæra*); and the modifications produced by the development of basal and radial plates, as in *Caryocrinus* and in normal crinoids, also present no difficulty. But it is not at once easy to see what stresses led to the irregularly pentagonal plates of *Eocystis*, in which pentactiny is superinduced on trisactiny (see Figs. 2–6). The following explanation is therefore offered.

If a piece of soft woven tissue be lightly stretched over a frame, and if a few equal weights be attached to various points in it, then the tissue will be dragged into folds leading from each of these weighted points to those adjacent. The direction and pattern of the folding will depend on the positions of the weight-points.

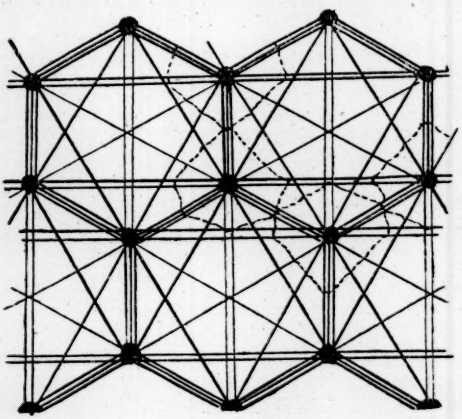


Diagram showing the lines of mechanical stress supposed to have produced the *Eocystis* plan of plate.

The problem before us, then, is to find the weight-points that would produce the fold-pattern of *Eocystis*. The three major lines of several plates, if plotted on paper, lead to an hexagonal pattern. This at first sight does not seem hopeful. But we note that the umbones of the plates, instead of lying at the centres of the hexagons, lie at the angles, or, in other words, at the nodes where the main lines of stress meet. This suggests that a hexagonal folding of the

stroma, such as may sometimes be seen in contracting homogeneous layers, preceded any extensive calcification, and that consequently the stereom was concentrated at the nodes. On this assumption, there arises a series of weight-points at the angles of alternating hexagonal spaces. Inserting these on our plan (Diagr. p. 52), we now proceed to fill in the other lines of stress that would flow from such an arrangement. These have been represented in the diagram with thicknesses roughly proportional to the distances between the weight-points. Thus a triple line connects the nodes along the sides of the hexagon; a stout double line connects the nodes horizontally; a faint double line connects those at the upper and lower angles, this being emphasized because the pull is intensified in this direction by gravity; a stout single line joins the node to the nearer pair of the remaining angles, and a faint single line joins it to the pair more remote.

Now take this diagram, worked out on purely *à priori* reasoning this night (December 5–6, 1917), and compare it with the lines of Figs. 2–6, drawn in 1900 before the problem had been formulated. Starting from a node there are lines of stress precisely comparable with the folds radiating from the umbo; and it will be observed that in the diagram no lines occur between the horizontal lines and the immediately adjacent main lines, just as the plates are folded very faintly or more often not at all in those spaces.

So much for the folds; now for the outline. If a circle be described with the node as a centre, and with radius equal to half the side of a hexagon, it will represent the tract that would naturally be calcified if calcification spread uniformly outward from the node until it met that spreading from the three adjacent nodes. Known facts of growth, however, suggest that the calcification would progress more rapidly along the main folds. Let the points where these are cut by the circle be joined by straight lines, and an irregular pentagon will result. This is shown in the diagram by dotted lines, but these, instead of being quite straight, are bent outwards slightly along the minor lines of stress. Thus is produced an outline agreeing so closely with the outline of Fig. 7 that the correspondence of theory with fact is truly astonishing.

The plates thus outlined in the diagram do not fill the whole space; more particularly is there a large free area round the centre of each hexagon. Probably the minor centres of calcification gave rise to a number of small intercalary plates.

If there be any truth in the hypothesis here put forward it follows that the *Eocystis* plan represents an evolutionary stage previous to that of the more usual pavement of hexagonal plates. One way in which the change might have been effected would be the fusion and growth of the plates about the centre of our supposed hexagon; this would produce a series of sub-hexagonal plates each surrounded by smaller ones, much as in *Deutocystis*. Or the original pentagonal plates, as they met, might be forced into a hexagonal shape, coupled with a strengthening of the fold within the fork of the ⅄; this would produce a plate like that of *Amygdalocystis*, which is not on the normal plan.

2. The two specimens labelled "Plates showing Marginal Pores" are in the form of impressions. One of them (E 7608) looks strangely like one-half of the pectinirhomb of a Glyptocystid; but the resemblance disappears when one examines a wax squeeze of it. I believe this specimen to be the impression of the sutural margin of a plate 3·8 mm. long, about ·6 mm. thick at the corners, and 1 mm. thick in the middle of the side; the sutural surface is covered with slightly irregular vertical ridges, about five to the millimetre, and these may have been crenelations fitting into corresponding notches in the adjacent plate. These ridges pass right down to the concavely curved margin, which I take to be on the inner side of the plate; but on the outer convexly curved, or, rather, gabled, side they stop short, so that the suture, if suture it be, was grooved. In the middle of the side, however, forming, as it were, the rooftree of the gable, is a rather large prominent vertical ridge, probably continuous with an axial fold or ridge. Clearly this impression has nothing to do with the stellate plates, and there is no adequate reason for supposing that the plate which made it belonged to the same organism.

The other impression, G. F. M. *e* (Fig. 8), appears to have been formed by the folded edge of a plate which had fallen obliquely into the mud. The space formerly occupied by the plate, having been subject to less compression, is thicker than usual. The walls of the cavity are marked by about seven ridges, varying in distinctness, and passing across its thickness. A squeeze of the cavity indicates that these ridges correspond to indentations or scollopings in the margin of the plate, lying between its folds. If several plates of this shape lay next one another in the thecal wall there would be the appearance of pores between them. It is quite possible that this is one of the stellate plates, and that others of them had a similar margin.

3. The impressions referred to Columnals are in the main of two kinds, long and short. The long ones vary in length from 1 to 3 mm., with a diameter from $\frac{1}{5}$ to $\frac{1}{3}$ their length. The diameter appears to be least about the middle; in other words the ossicles were slightly dice-box shaped (Fig. 15). At each end was a conical excavation penetrating to a depth about equal to the width of the respective columnals. In the impression this appears as a deltoid patch of matrix, and is sometimes so pronounced as to give the impression a bifurcate appearance, G. F. M. *g* (Fig. 14). In a few cases this may be seen at both ends, but more often the matrix has been split obliquely to the long axis of the columnal, so that in a single half of the impression this cone appears only at one end. The sides of the columnals seem to have been marked with irregular vertical striæ, perhaps due to the original fascicular structure of the stereom (Fig. 10, *b*).

The short columnals leave an impression that approaches a square, but has the two sides slightly inflected. E 7607 has a length of about ·75 mm. and shows no cone at the ends. One of Dr. Matthew's specimens (*d*, Fig. 13) is about ·25 mm. long, and has a flattened cone at each end.

There is no direct evidence that these columnals belonged to the

animal that owned the stellate plates. Their association in the rock suggests that they did so, but the relatively small size of so many suggests that they did not.

On specimen G. F. M. *d*, a worm-like body, about 11 mm. long and 1·25 mm. wide, and marked with obscure transverse striæ, is labelled by Dr. Matthew "*Eocystites primæva*, stem!" One end lies against a stellate plate, but there seems no other reason for this ascription.

4. The Undetermined Plates include many obscure impressions and patches of various sizes and shapes—or rather absence of definite shape. There seems no reason why some of them should not belong to *Eocystis*, nor any why they should. There are several examples of a trihedral sub-pyramidal impression, probably produced by the angle of a plate. The wax squeeze drawn (Fig. 19) is taken from the largest of these (*k*). Another type is represented by *j*, the squeeze of which (Fig. 18) shows curved sides meeting in a rounded ridge with a wide angle and a rather sharp edge or lip in front. Other forms are shown in *h* and *h'* (Figs. 16, 20), but without figuring every specimen one cannot convey an idea of the variations in shape of these rounded surfaces. Among the fragments is an apparent spine, *l*, possibly the infilling of a columnal (Fig. 17). There are also some minute rounded impressions, which may represent the intercalary plates of *Eocystis*.

From the various plates and ossicles now described it is not easy to reconstruct the form of *Eocystis*. We can recognize the stellate plates of the theca and the biconcave columnals, and we are led by their numbers and their association to suppose that both belonged to the same form. If this be so, then *Eocystis* possessed a flexibly-walled theca borne on a slender flexible stem. One can detect no obvious brachiolars, and the undetermined ossicles seem too large to be thus interpreted. Possibly they represent proximal columnals such as occur in the Heterostelea, to which group *Trochocystis* belongs. Comparison may profitably be made with the stem of *Cothurnocystis* (Bather, 1913, "Caradocian Cystidea from Girvan," Trans. Roy. Soc. Edinburgh, xlix, pt. ii, No. 6, §§ 200–6, text-figs. 19–23).

If *Eocystis* be rightly referred to the Heterostelea, it by no means follows that it belongs to the Trochocystidæ. The stellate plates are unlike the close-fitting hexagonal plates of *Trochocystis* (Barrande, 1887, *Syst. Sil.*, *Cystidées*, pls. iii, iv), and there is no trace of the characteristic marginals. For similar reasons *Eocystis* cannot be referred to the Cothurnocystidæ or Ceratocystidæ, and still less to the Anomalocystidæ. It may have resembled *Dendrocystis* in the irregular arrangement of its thecal plates, but it differed in the cylindrical or dice-box columnals.

For the interpretation of *Eocystis* it will therefore be necessary to consider other forms than *Eocystis primæva*, both such forms as may have been referred, with or without hesitation, to *Eocystis*, and such obscure remains as may have received yet other names. That inquiry may form the subject of a future article.

EXPLANATION OF PLATE V.

Eocystis primæva.

Fig.

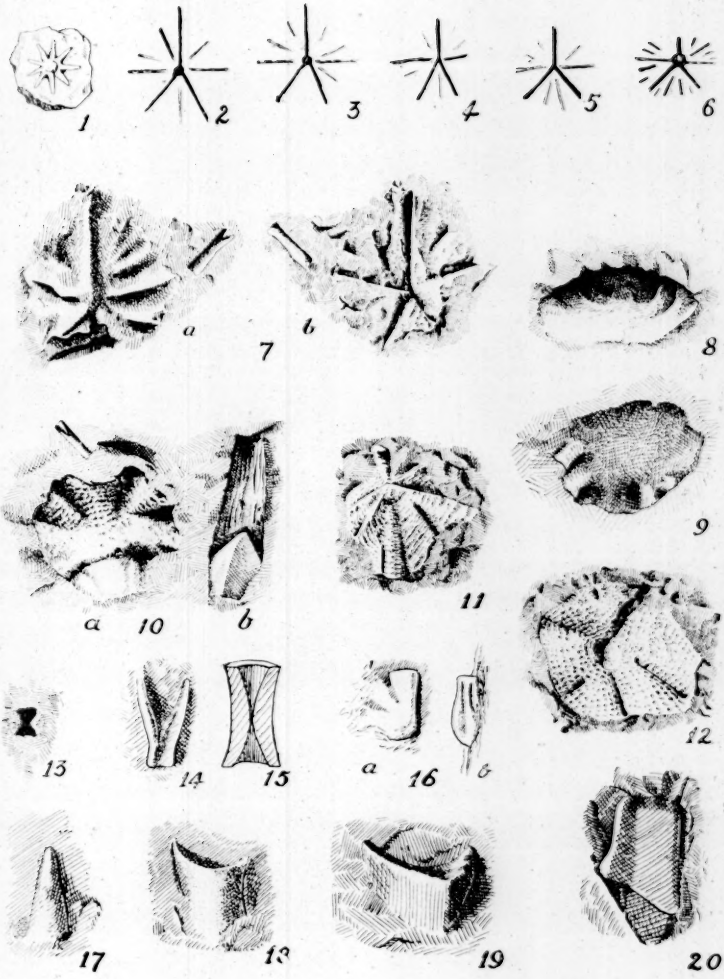
1. The holotype, reproduced from Dawson's fig. 220.
2–6. Diagrams illustrating the direction and strength of the folds in five plates, viz. (2) E 7611, (3) E 7604, both being imprints of the inner face; (4) G. F. M. *f*, (5) G. F. M. *e*, (6) E 7603, these being imprints of the outer face. In (2) to (5) there are ten folds to each plate; in all there can be distinguished three main folds ⅄, and two folds nearly as strong running east and west; subsidiary folds occur in the spaces between all of these, except the space in the E.S.E. sector (as seen in the external imprint), and are rare in the corresponding W.S.W. sector.
7. E 7602, showing a plate and a columnal; (*a*) external, (*b*) internal imprint. × 4 diam.
8. G. F. M. *c*. An imprint of a plate supposed to show marginal pores, as received. × 8 diam.
9. The same imprint after removal of more matrix. × 8 diam.
10. E 7602. (*a*) External imprint of a plate; (*b*) columnal. × 8 diam.
11. G. F. M. *a*. Internal imprint of a stellate plate of normal form. × 4 diam.
12. G. F. M. *b*. External imprint of a plate. × 4 diam.
13. G. F. M. *d*. Imprint of columnal (?). × 8 diam.
14. G. F. M. *g*. Squeeze from imprint of a columnal. × 4 diam.
15. Suggested reconstruction of a columnal in solid section. × 4 diam.
16. G. F. M. *h'*. Wax squeeze of an undetermined plate, (*a*) from above, (*b*) from the side. × 4 diam.
17. G. F. M. *l*. Wax squeeze of an external imprint, possibly the infilling of a columnal. × 4 diam.
18. G. F. M. *j*. Wax squeeze of an external imprint of an undetermined plate. × 4 diam.
19. G. F. M. *k*. Ditto.
20. G. F. M. *h*. Ditto.

Drawings by G. C. Chubb, from the specimens and from pencil drawings by the author.

II.—Notes on some South Staffordshire Fire-clays and their Behaviour on Ignition.

By Arthur Hubert Cox, M.Sc., Ph.D., F.G.S.

ALL geologists are familiar with those changes effected in argillaceous rocks under the influence of heat from igneous intrusions, changes that result in the formation of such rocks as chiastolite-slate, andalusite-hornfels, etc. It is therefore somewhat surprising that the changes produced during the artificial heating of clays should remain comparatively unknown to the body of geologists, although such changes are produced every day on a large scale during the baking of clays for the manufacture of pottery of various kinds. These changes have, indeed, been very little studied from the mineralogical standpoint. It might at first sight be expected that any changes brought about artificially by the action of heat on a clay would compare somewhat closely with those resulting in an argillaceous rock when subjected to contact-metamorphism—at any rate in the normal case of the latter change—when there is no transference of material from the igneous to the sedimentary rock. Yet such is hardly the case; there are certainly points of resemblance, but there are also very notable differences. It must be made clear that the clays used in the experiments to be described were



F. A. Bather and G. C. Chubb del. Bale imp.

EOCYSTIS PRIMAEVA HARTT.

It seems clear, then, that the clays examined consist entirely of crystalline material, and that amorphous matter is absent altogether. On the other hand, Dr. Mellor has recently adduced evidence from the heating-curves of some South Staffordshire fire-clays for the existence in them of "clayite", which he regards as being amorphous.[1] But, as stated above, no amorphous matter could be found by mineralogical examination.

The mere fact that the clay-base is crystalline and not amorphous does not, however, prevent the fine material form acting in certain respects like a colloid. For example, if suspended in water, it may be readily precipitated by the addition of certain electrolytes, particularly by acids.

It is unnecessary for the purpose in view in this communication to enter into the vexed question as to the actual mineralogical composition of this clay-base. It certainly seems, however, to act as a single substance with definite optical characters, and therefore presumably definite chemical composition. It is, moreover, significant that the more the fine material of a clay can be purified, the more nearly does it approach kaolin, $Al_2 O_3$, 2 $Si O_2$, 2 $H_2 O$, in chemical composition. It is true that there are certain marked differences of appearance between the substance of the clay-base of these South Staffordshire clays and the kaolin in a china-clay. These differences appear to be intimately connected with the variation in their plasticity, the fire-clay being highly plastic, whereas the china-clay is only slightly plastic.

2. Arenaceous material was present in all the clays examined, and often in amounts surprisingly large, considering the typical argillaceous appearance of hand-specimens. The arenaceous material consists for the most part of quartz-grains exactly comparable with those in a normal fine-grained sandstone. Grains other than quartz are not abundant, but a certain number of chert-grains were usually to be found. Undoubted felspar was only rarely observed, and the same was true for clastic micas. Isolated examples of heavy minerals, such as tourmaline, zircon, rutile, etc., were usually present, but in amounts so small as to be negligible in affecting the properties of the clays.

Besides the larger, more or less rounded, and obviously detrital sand-grains, there were also present innumerable minute flakes and chips of quartz. These passed downwards into the finest quartz-dust, almost comparable in grain with the material of the clay-base itself. It is evident that, owing to its very fine grain it would prove almost impossible to separate much of this free silica from the true clay material by any mere process of washing. In view of the occurrence of chert-grains among the sandy material of the clays, it seems very possible that some of this quartz-flour may have been derived from the disintegration of cherty rocks. On the other hand, it may have had its origin in the small secondary quartzes that would result from the alterations undergone by many of the minerals of the old land surface then undergoing denudation. In

[1] Trans. Eng. Ceramic Soc., vol. xvi, p. 83, 1916–17.

any case it is evident that this fine quartz-flour is of true detrital origin, and not an authigenous constituent arising as the result of secondary changes in the clay itself.

Among the minor constituents of the clays, carbonaceous material can invariably be recognized in the hand-specimen; this probably plays an important part in determining the porosity of the burnt clay. Pyrites occurs dispersed as a fine flour, and a certain amount of oxides of iron may also be recognized.

The first stage of ignition consisted in heating the clay (made plastic with water and then dried) to a temperature of 1000–1080° C. for about fifteen minutes. The main changes during this preliminary heating were: (1) the burning-off of carbonaceous material, (2) the oxidation of ferrous compounds, involving a colour-change from the original dark-grey to a paler and more yellowish tint, (3) an almost complete loss of the combined water. The originally soft clay is thus converted into a "biscuit-clay", as it is termed by the pottery manufacturers. The biscuit is highly porous, and therefore can absorb water, but it cannot be reconverted into a plastic material comparable with the original clay. Some important change has therefore taken place during the burning, and the biscuited clay has lost all power to combine with water. Curiously enough this change, presumably chemical, is not accompanied by any corresponding change in the physical characters as revealed by the microscope, although the macroscopic change is obvious enough. The biscuited clay presents in fact, so far as I could observe, very much the same appearance under the microscope as the original clay.

When, however, the ignition is carried out at a higher temperature, about 1500° C., various interesting chemical and mineralogical changes begin. The clay now gradually "vitrifies", owing to the partial fusion of the less refractory constituents, resulting in the formation of material that is practically a glass. The amorphous nature of the new material is not, however, readily established in the early stages of the process. The difficulty arises both from the minuteness of the particles, and the extent to which the newly-formed vitreous material is crowded with as yet unaltered crystalline material. Also the glass, as first formed, is in a state of strain, since the vitrification takes place without the material ever becoming actually liquid in the popular sense. Accordingly the glass is birefringent in the early stages of the process. As the heating is continued, more and more of the original crystalline material loses its identity, and the resulting vitreous substance thus has more chance to adjust itself. This latter factor is, however, partly counterbalanced by the fact that the newly-formed glass occupies more room than the crystalline material, as is shown by the respective densities. Owing to slight flow-movements, a minute, irregular streakiness soon appears. The strain is thereupon somewhat lessened, so that the material becomes, over small areas, quite isotropic.

The vitreous material can then be seen gradually to corrode and absorb even the larger sand-grains, so that an almost uniform product is finally obtained. As stated above, all these changes take place without the material ever becoming really liquid, always provided that

one is dealing with a truly refractory clay, and accordingly the ignited article retains its original shape. The resulting product, in fact, does not present to the naked eye any marked difference to the biscuit-clay, save that it appears, perhaps, to be a little more compact. A careful examination, however, reveals slight traces of fusion having taken place, and the material no longer tends to crumble easily as does the biscuit-clay. Actually, however, the specific gravity is lowered, as is only to be expected when crystalline material passes over into the amorphous condition.

A high-grade clay will then remain in much the same condition, even when subjected to considerably higher temperatures, temperatures up to 1600° C., or even in certain special cases up to 1700° C. Vitrification is naturally progressive, but still the clay does not soften appreciably until these temperatures are reached. An inferior clay, on the other hand, under the same conditions melts down more or less completely, naturally changing its shape completely during the process. All stages from readily fusible clays to highly refractory ones may be obtained. It was found that the softening-point of lower-grade fire-clays was considerably raised if the coarse sand-(quartz-) grains were first removed by washing. Conversely these coarser portions from the clay, when treated alone, were found to have a very low softening-point, becoming quite fluid at the higher temperatures. This point will be further referred to below.

Returning to the more refractory clays, with increase of temperature an entirely new change begins, the results of which become more and more marked the longer the clay is subjected to the higher temperature. The new change consists in a *devitrification* of the glass owing to the separation of tiny needles of some crystalline substance. This devitrification may set in before the vitrification is quite complete, in that the larger quartz-grains may not have been finally absorbed by the fluxing groundmass. In specimens exposed to a very high temperature for many weeks the devitrification has proceeded to a very considerable extent, although it still remains incomplete. The material so obtained consists of a colourless and completely isotropic glass enclosing great numbers of small crystals. The crystals, in fact, are so numerous and so small as to render the glass opaque except in very thin section, when the glass appears as if it contains a vast number of little globules. Under favourable conditions, and with high powers, the apparent globules are seen to be really angular, and exceptionally they are seen to be elongated in prismatic form.

The crystals were isolated by means of cold dilute hydrofluoric acid, which remained without action on them. They all proved to be acicular in form, with a high refractive index—about 1·66—straight extinction, and + character. They consist, therefore, of a sillimanite. There appear to be no substances present other than sillimanite and the clear glass. In one specimen, which had been exposed to a high temperature for many weeks, and in which, therefore, the crystallization may reasonably be assumed to be complete, the amount of sillimanite was found to vary between 29·0 and 33·3 per cent.

The separation of the crystalline sillimanite, with a specific gravity 3·23, naturally involves a considerable contraction. The result is the formation of a drusy material, in which the cavities are of comparatively large size and quite irregular in shape.

The marked tendency to the production of sillimanite when substances approximating in composition to kaolin are strongly heated, has been observed on various occasions. Wernadsky[1] obtained it from artificial mixture of Al_2O_3 and SiO_2, and also from kaolin. He further noted its formation in crucibles and fire-bricks from various fire-clays. It was also observed by Mellor[2] in porcelains made from mixtures rich in china-clay and felspar fired at temperatures over 1300° C.[3] It is a remarkable point that the sillimanite formed from the fire-clays seems not to have the same composition as the naturally-occurring sillimanite of the rocks. The natural product is always stated to have the composition Al_2SiO_5, or Al_2O_3, SiO_2, where the $Al_2O_3 : SiO_2$ ratio is as 1 : 1. The artificial product, however, seems to have the ratio 11 : 8, as shown by the following figures :—

		Calculated for	
		11 Al_2O_3, 8 SiO_2	Al_2O_3, SiO_2
SiO_2 30·07	28·89	29·96	37·03
Al_2O_3 69·93	71 11	70·04	62·97

The analysis was carried out by volatilizing the SiO_2 from the crystals (obtained as mentioned above, p. 62) as SiF_4, the Al_2O_3 being left as such on ignition.

A similar result was obtained by Wernadsky[4] for sillimanite from fire-clays, whereas the sillimanite formed from artificial mixtures of Al_2O_3 and Si O had the normal composition Al_2SiO_5, whatever the proportions of Al_2O_3 and SiO_2 in the original mixture.[5]

Sillimanite of the composition 11 Al_2O_3, 8 SiO_2 was recorded by Sainte-Claire, Deville, and Caron[6] as formed by the action of AlF_3 on SiO_2, but, so far as I am aware, there is no case recorded of an analogous product occurring in the metamorphic rocks. The question is, however, deserving of further investigation.

Sillimanite is a chemically simple substance, and it is well known that the fusing-point of a chemically simple substance is lowered by the introduction of impurities. Now all the clays examined contained sandy (quartzose) material giving an $SiO_2 : Al_2O_3$ ratio much greater than that in sillimanite. It appeared probable, therefore, that the refractoriness of the clays would be increased by removing the excess of sand. This was actually found to be the case, as already mentioned (p. 60). Since, however, the clays all contain much

[1] Bull. Soc. Min. France, vol. xiii, p. 260, 1890.
[2] Journ. Soc. Chem. Ind., vol. xxvi, p. 375, 1907.
[3] For a summary of the effects of heat on kaolin and kaolinite, see J. A. Howe, *Handbook to the Collection of Kaolin* . . . (Mem. Geol. Surv.), 1914, p. 151, with references.
[4] Bull. Soc. Min. France, vol. xiii, p. 270, 1890.
[5] Op. cit., p. 263.
[6] C.R., vol. xlvi, p. 766, 1858.

free silica in the form of a quartz-flour, the $SiO_2 : Al_2O_3$ ratio still remained in excess of that demanded by sillimanite. This excess of silica could not be readily removed by any simple process of elutriation in consequence of the extremely fine-grained character of the quartz-dust, the particles of which become comparable in size with those of the clay-base itself.[1] In order, therefore, to bring the $SiO_2 : Al_2O_3$ ratio down to that demanded by sillimanite, alumina in various forms was added to the clays in various amounts. The refractoriness of the clays was then again found to be further increased, or in other words the softening-point was very considerably raised.

Turning now to a comparison of the changes occurring in artificially heated clays with those in contact-altered argillaceous rocks, there are certain points of resemblance, as is only to be expected. But there are also, in most cases, some very interesting differences in behaviour.

In the first place it will be noted that the aluminium-silicate formed under artificial heating was the high-temperature form *sillimanite*. In no case was the low-temperature form *andalusite* observed, and, so far as I am aware, the artificial production of that mineral has never been recorded.

In contact-altered rocks, on the other hand, both minerals may occur, sometimes exclusively the one or the other, sometimes both together, whereas in yet other cases *kyanite* is the characteristic mineral.

Again, the more obviously contact-altered rocks are almost always holocrystalline, belonging to, or approximating to, the granular rocks classed as *hornfels*. Cases of vitreous rocks produced by contact-action are the exception rather than the rule. We have, however, examples of such vitreous rocks in the *buchites*, or vitrified phyllites, British specimens of which have been described from Argyllshire by Dr. Flett.[2]

In these vitrified phyllites, however, the newly-formed aluminium silicate occurs, not in the pure state as andalusite or sillimanite, but combined with MgO as cordierite. This, however, is merely the result of the high magnesia-content of the original phyllite, in which the magnesia was present in the form of chlorite.

Apart from the buchites certain other examples of contact-altered rocks are known that match in all respects the products formed by the continued ignition of fire-clays. They are rocks that occur as xenoliths in basic intrusive rocks in Mull. A complete account of the phenomena there shown is not at present available, but some mention of the rocks has been made by the officers of the Geological Survey in recent *Summaries of Progress*. These xenoliths,

[1] It has been shown possible to remove this silica-dust by osmosis, a process that has been claimed to yield excellent results in other cases [W. R. Ormandy, Trans. Eng. Cer. Soc., vol. xii, p. 36, 1912–13, and vol. xiii, p. 35, 1913–14]. When a suspension of clay is electrolized the quartz remains neutral, the clay-substance goes to the − pole, while most of the impurities go to the + pole.

[2] *Geology of the Country near Oban and Dalmally* (Mem. Geol. Surv.), 1908, p. 129, with references.

derived from highly aluminous shales, have been converted into *sillimanite-hornfels*, that is, rocks consisting "entirely of minute slender needles of sillimanite set in a colourless glassy base".[1] One such rock has been analysed.

It is noteworthy that these vitrified rocks occur, as a rule, in association with those basic intrusive rocks, such as olivine-dolerites, camptonites, monchiquites, etc., that show a tendency to contain more or less analcite. The magmas that give rise to such rocks, therefore, must have been richer in water-vapour than is normally the case in igneous magmas. Accordingly it may well be that the vitrifying action which they exerted on the surrounding sediments was facilitated by the presence of the hot vapours. This conclusion is supported by the analyses quoted by Dr. Flett,[2] which show an accession of water to the vitrified rock as compared with the unaltered rock.

It may well be that the vitrification of the ignited fire-clays was likewise facilitated by the presence of slight traces of water that had escaped volatilization during the preliminary heating to the biscuit stage. In this connexion it may be noticed that most glassy rocks, such as the pitchstones and tachylites, show a high water-content. Obsidians, however, form an exception to this rule.

Summarizing the results we may say that the artificially heated clay, originally cryptocrystalline in texture, shows first a vitrification, followed by a partial devitrification, resulting in the formation of the high-temperature mineral sillimanite. The texture still remains very fine-grained.

The naturally heated rocks, on the other hand, do not normally show signs of any vitrification having taken place. Rather do they pass into rocks of the holocrystalline hornfels type with a medium to coarse texture, and in which low-temperature minerals may be found either alongside, or to the complete exclusion of, high-temperature minerals. Such contact-action was therefore brought about by a comparatively small rise of temperature, extending, however, over a considerable time.

Exceptionally there do occur vitrified rocks comparing more closely with the artificially altered fire-clays, but such vitrified rocks are only associated with special types of igneous rocks, and water-vapour probably played an important rôle in determining their special features.

I have to express my indebtedness to Professor Sir Herbert Jackson, K.B.E., F.R.S., for his most valuable advice and for reading through this paper, and to the Controller of the Optical Munitions and Glassware Department of the Ministry of Munitions of War for permission to publish these results of an investigation primarily undertaken on behalf of that Department, and carried out in connexion with Sir Herbert Jackson's researches on fire-clays for the Clay Research Committee of the Institute of Chemistry.

[1] A. E. Radley, *Summary of Progress for 1914* (Mem. Geol. Surv.), 1915, p. 57.

[2] Op. supra cit., p. 132.

III.—The Lias of South Lincolnshire.

By A. E. Trueman, M.Sc., F.G.S., formerly Research Scholar, University College, Nottingham.

Introductory.

THE area to be described is that part of the Lias outcrop extending from Lincoln southwards to Barrow-on-Soar and Grantham, and includes south-west Lincolnshire and small portions of north-east Leicestershire and east Nottinghamshire (see Map, Fig. 1).

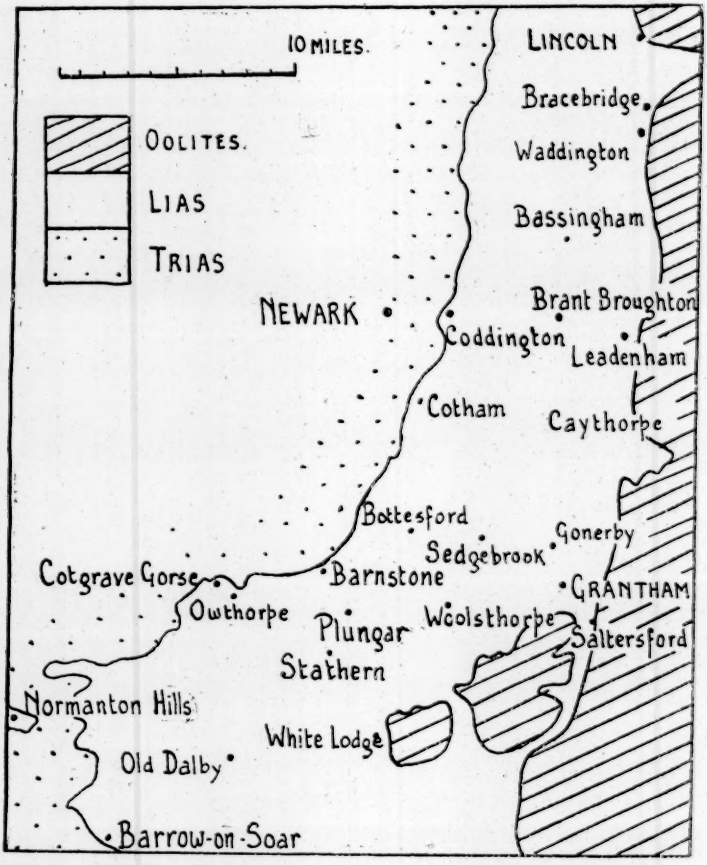


FIG. 1.—Diagram map of South-West Lincolnshire to show the position of exposures. (Adapted from the Index Map of the Geological Survey.)

The rocks of this district were mapped by the Geological Survey, and an account of some of them was published in 1885 [1] and 1888 [2];

[1] *The Geology of South-West Lincolnshire* (Mem. Geol. Surv.), 1885.
[2] *Country around Lincoln* (Mem. Geol. Surv.), 1888.

the south-western part of the area has been resurveyed and described in more recent memoirs. A summary of the geology of the area was prepared in 1910 by A. J. Jukes-Browne,[1] but except for these publications the literature is scattered and consists mainly of short papers; details of these are given where they are referred to.

It will therefore be seen that the Lias as a whole has not been studied in this neighbourhood for some thirty years. During this time the Lias of other areas has been carefully investigated by numerous workers, resulting in great advancement in our knowledge of the succession. This work has been undertaken in order to determine whether the Lincolnshire succession agrees with that recorded elsewhere.

Since there are no continuous sections available for study, the work has been confined to artificial exposures in limestone and ironstone quarries and clay pits. Many of the exposures examined by previous writers have long been abandoned, owing to the closing of the hand-brickyards in the area;[2] moreover, on account of the war, many of the remaining yards have been temporarily closed, and consequently it is often a matter of some difficulty to collect fossils in situ. Thus it may be expected that the faunal lists will be considerably increased and much fresh detail obtained by further work when the pits are reopened. While only scattered observations may be made on the Lower Lias clays, it has been possible to make a detailed comparison of the Middle and Upper Lias. In the course of the work samples of clay from each exposure have been "washed" and the residue examined for Foraminifera, details of which are given in the lists.

It is necessary to state that the interpretation of "zone" adopted in this paper is that given by Mr. W. D. Lang,[3] who emphasized the fact that once a zone is defined its boundaries "theoretically are fixed for ever". The so-called zones which have been used at Lincoln have often been unsatisfactory; for example, the deposits known as *commune* zone in Lincolnshire and Yorkshire are quite different in age. If zonal terms were correctly used, such a contradiction would be impossible. In this paper the hemeral terms introduced by Mr. S. S. Buckman, which have sometimes been miscalled zones, have in the Upper Lias been used as sub-zones of Oppel's cumbersome zone of *Posidonomya Bronni*.

In the course of this work much help has been received from numerous workers in Lincolnshire, especially Mr. A. Smith, of Lincoln Museum, and Mr. H. Preston, of Grantham, who generously placed at my disposal their detailed knowledge of the district. For permission to examine specimens I am also grateful to Mr. G. W. Lamplugh and Mr. H. A. Allen, of the Jermyn Street Museum (Geological Survey); and to Mr. E. E. Lowe, of Leicester Museum. Mr. S. S. Buckman has kindly named several ammonites and assisted

[1] *Lincolnshire*, Jubilee Vol., Geol. Assoc., 1910.

[2] A. E. Trueman, "Lias Brickyards in South-West Lincolnshire": Trans. Lincs Nat. Union, 1917.

[3] W. D. Lang, "Geology of Charmouth Cliffs, etc.": Proc. Geol. Assoc., 1914, p. 307.

in other ways. Much help in the field has been given by Messrs. W. E. Howarth and W. D. Varney, while at all stages of my work Professor H. H. Swinnerton has offered advice and encouragement, for which I am greatly indebted. I have also to thank Professor T. F. Sibly for reading my manuscript and making various suggestions.

The general succession of Liassic rocks in this area is as follows:—

		Feet.
Upper Lias.	Shales with concretions . . about	100
	Thickness decreasing northwards.	
	(No higher beds than the subzone of *subcarinatum* are present at Lincoln, and the subzone of *fibulatum* at Grantham.)	
Middle Lias.	*a*. Marls and Ironstone (present in South Lincolnshire. Only thinly represented around Lincoln).	3–30
	b. Shales	30–70
Lower Lias.	*a*. Blue, black, and grey shales, with nodules and bands of earthy limestones . about	700
	b. Hydraulic limestones . . .	25

It will be most convenient to consider the rocks in the following order:—

1. Hydraulic Limestones.
2. Lower Lias Clays.
3. Middle and Upper Lias.
   (*a*) Lincoln, (*b*) Grantham.

1. Hydraulic Limestones.

The number of Hydraulic Limestone quarries now being worked is considerably smaller than it was a few years ago, but Lias cement is still made at Barnstone, Owthorpe, and Barrow-on-Soar; a large quarry near the railway at Normanton Hills, East Leake, has only recently been abandoned, and a complete section of the beds from the Keuper to the Lower Lias is still visible, while the junction of Rhætic and Lias is also exposed at Cotgrave Gorse. The limestone quarries east of Newark have not been worked for several years, and in only one of these is the succession clear. However, the construction of trenches at the Royal Engineers' Depôt at Coddington has made it possible to study the sequence in the Newark neighbourhood. Colonel H. Jerome kindly gave permission to study this section.

An examination of the available sections and a comparison of the diagrams which have been constructed, as suggested by the late Dr. Vaughan,[1] to show the ranges of the fossils, indicates that there are three types of transition from Rhætic to Lower Lias in this district, viz.:—

1. The type seen at Owthorpe, a full account of which was given in a previous paper;[2] it was pointed out that the lowest beds do not contain *Psiloceras planorbis*, the zonal ammonite, which is likewise absent in the lowest beds at Cotgrave Gorse, Normanton Hills, Barnstone, and Newark. T. Wright noticed that in the South of

[1] A. Vaughan, "Lower Beds of the Lower Lias of Sedbury Cliff": Q.J.G.S., vol. lix, p. 396, 1903.

[2] A. E. Trueman, "Fauna of the Hydraulic Limestones": Geol. Mag., Dec. VI, Vol. II, p. 150, 1915.

England also the lowest beds of the Lias did not contain any ammonites,[1] while the numerous sections recorded in the Memoirs of the Geological Survey indicate that this condition is of frequent occurrence.[2] Indeed, it has been suggested that these lowest beds should be considered as of pre-*planorbis* age,[3] and called "*Pleuromya* and *Ostrea* Beds".[4] Their age and relationships were discussed in the paper referred to.

2. At Barrow-on-Soar *Psiloceras planorbis* occurs in beds which are the equivalent of the so-called pre-*planorbis* beds of other localities.

3. The third type, associated with the Sun Bed, seen at Cotgrave Gorse, has indications of a slight break in sequence at the top of the Rhætic.

The first type of transition from Rhætic to Lias may be seen at Owthorpe, Barnstone, and near East Leake, where the sections all conform more or less to the following:—

		Feet.
Angulata zone.	Dark-blue shales with Selenite crystals and with rare limestone nodules, with *Schl. angulata*	10
Planorbis zone.	Dark-blue shales . . . . . about	9
	"Roof Bed," a massive bed of yellow earthy limestone with *Lima* and *P. planorbis*	1
	Flaggy beds; fissile limestones or shales with abundant *C. Johnstoni*	2
	Earthy limestone and shales with *P. planorbis* . .	3
	,, ,, without ,, ...	2
	Fine blue limestone with Oyster Beds and *Pleuromya* .	2
	Hard blue shales with irregular limestones and *Modiola minima*	5

The beds with *Schlotheimia angulata* were not exposed except at Barnstone, where they may be seen at the south-eastern end of the quarry. The sections at Coddington, in the trenches two miles east of Newark Church, show about 20 feet of hard limestones and shales belonging to the *planorbis* zone. The upper beds in this district are much coarser than those in the south of the county, but the section does not differ in any essential points from that noted by Wilson[5] in the same neighbourhood at Cotham.

Only one section of Lower Lias can now be examined in the neighbourhood of Barrow-on-Soar, and this is situated north of the railway near Sileby, one and a half miles west-south-west of Barrow Church. The details are similar to those given by H. B. Woodward[6] and M. Brown.[7] Comparing these two interpretations, it will be noted first that Brown assigned to the Rhætic certain beds, about

[1] T. Wright, "Lower Lias and *Avicula contorta* zone": Q.J.G.S., vol. xvi, p. 374, 1860.

[2] See, for example, H. B. Woodward, *Lias of England and Wales* (Mem. Geol. Surv.), 1893, pp. 137, 141, 145.

[3] L. Richardson, *Geology of Cheltenham*, 1904, p. 38.

[4] S. S. Buckman, *Yorkshire Type Ammonites*, vol. i, p. xvi, 1910.

[5] E. Wilson, *Geology of South-West Lincolnshire* (Mem. Geol. Surv.), 1885, p. 27.

[6] H. B. Woodward, *Lias of England and Wales* (Mem. Geol. Surv.), 1893, p. 169.

[7] In *Geology o Country near Leicester* (Mem. Geol. Surv.), 1903, pp. 22–3.

4 feet in thickness, which Woodward had considered as Lias. These are unfossiliferous earthy limestones and shales, unlike those usually found in the Rhætic, and are probably of Liassic age, but the absence of a continuous section in this neighbourhood makes it undesirable at present to give a definite statement. Even if these beds should prove to be the equivalents of the lowest beds elsewhere, the entrance of *P. planorbis* must have been distinctly earlier at Barrow than in any of the other localities examined.

It will be further noticed that in Brown's table the "Roof Bed" at Barrow is included in the *angulata* zone, although Woodward, who did not attempt to separate the *planorbis* and *angulata* zones, had previously recorded *P. planorbis* from the same bed. As a matter of fact, the lowest definite occurrence of *S. angulata* is some 10 feet higher. Brown apparently considered "*Schlotheimia catenata*"[1] to indicate the lower part of the *angulata* zone, but this is doubtful; Wright inferred that his example of "*S. catenata*" from Barrow was from the *planorbis* zone,[2] and Hyatt also showed that "*S. catenata*" most frequently occurs in the upper part of the *planorbis* zone on the Continent.[3]

Further, it must be noticed that the Roof Bed of Barrow is almost identical in lithology and fossil content with the bed at Barnstone and elsewhere, to which I have applied the same name, and that in these places *P. planorbis* occurs above this level. There seems little doubt, therefore, that these beds with *S. catenata* (*Waehneroceras*), should be assigned to the *planorbis* zone; the sudden dominance of *Waehneroceras* in the Barrow-on-Soar district is merely a local characteristic comparable with the relatively early appearance of *P. planorbis* in that neighbourhood. Thus the general section at Barrow is as follows:—

		ft.	in.
Angulata zone.	Blue shale	6	0
	Impersistent limestone with *S. angulata*		3
	Blue shale with *S. angulata*	6	0
Planorbis zone.	Dark-blue pyritic shale, with great abundance of *Waehneroceras* spp. and *C. Johnstoni*	10	0
	Roof Bed. Yellow earthy limestone with *P. planorbis*, *C. Johnstoni*, and *Lima*	1	0
	Hard blue shales with impersistent flaggy limestone	4	0
	Blue shales and pale-blue limestones with *P. planorbis*, insect remains, and algæ	11	0
	Earthy limestone and brown shales, unfossiliferous	4	0

It is apparent that the fossil succession is very different from that which has been observed elsewhere, both in this area and in many other parts of the country.

A third type of transition from Rhætic to Lias is seen in a small stone quarry near Cotgrave Gorse, one and a half miles east-north-east of the section described at Owthorpe. The uppermost bed of

[1] The forms known as *Schlotheimia catenata*, d'Orb., should be referred to several species of the genus *Waehneroceras*. See Table of Fossils.

[2] T. Wright, "Monographs of Lias Ammonites": Palæont. Soc., pl. xix, figs. 5–7.

[3] A. Hyatt, "Genesis of the Arietidæ": Smiths. Contrib. Knowl., 1889, Tables.

Hydraulic Limestone Fossils.

[a = Lower *Planorbis* zone ("pre-*planorbis*" beds), b = Upper *Planorbis* zone, c = *Angulatus* zone.]

	Barrow-on-Soar.	Normanton Hills.	Owthorpe	Cotgrave Gorse.	Barnstone.	Coddington.
Saurian remains	a b	a b	a b	a	a b	
Fish teeth and scales	a b	a	a b	a	a b	
Psiloceras planorbis, Sow.	a b	b	b		b	b
Caloceras Johnstoni, Sow.	b c	b	b		b c	b
C. cf. *Belcheri*, Simps.	b				b	
Waehneroceras frigga, Wah.	b					
W. exechoptychum, Wah.	b					
Schlotheimia angulata, Sch.	c				c	
Belemnites cf. *acutus*, Mill.			b			
Turbo spp.			b			
Avicula cygnipes, Y. & B.			a	a		
Lima (*Plagiostoma*) *gigantea*, Sow.	b c	b c	a b	a	a b c	b c
L. hettangiensis, Terq.	b					
L. pectinoides, Sow.	b				b	
Monotis cf. *fallax*, Pflücke						b
Modiola minima, Sow.	a b	a b	a b	a	a b	a b
Ostrea liassica, Strickl.	b c	a b c	a b	a	a b c	b c
O. sp.		b	b		b	
Pecten pollux, d'Orb.	b					
P. Thiollieri, Mart.	a b	b	a b		a	a
Pinna sp.			b			
Pleuromya crowcombeia, Moore		a	a			
P. sp.						b
Cidaris Edwardsi, Wright	a b	a b	a b	a	a b	a b
Pentacrinus psilonoti, Qu.					a	
Holothurian spines (? *Cucumaria*)		a b	a b		a	
H. plates (? *Synapta*)			b			
Worm bores			a	? a		
Cytheridea ellipsoidea, Jones	? a	a b	a b	a	a b	a b
C. cf. *Moorei*, Jones			a			
Dentalina pauperata, d'Orb.		b				
D. tecta, Terq.		a				
Frondicularia nodosaria, Terq.		a	a			
F. Terquemi, d'Orb.		b	b		b	
Involutina liassica, Jones			a			
Lagena elongata, Ehrenb.			a			
L. cf. *ovata*, Terq.			a			
Marginulina Römeri, Reuss.		b				
Nodosaria raphanistrum, Linn.	?	a	a			
N. raphanus, Linn.		a b	a b	a	a b	a
N. radicula, Linn.			a		a	
Algæ, Fucoid	a					
Wood fragments	a b		b		a b	

the Rhætic in this quarry is similar to the one which has been described in the South of England as the "Sun Bed".[1] The section was given briefly by the Survey,[2] but more fully it is as follows:—

	ft.	in.
Blue shales with Echinoid spines	2	0
Earthy limestone with *Ostrea*, *Modiola*, and *Lima gigantea*		2
Hard blue limestone with *Modiola*		5
Laminated blue shale	1	3
Sun Bed. Purple limestone	1	6

As shown in Fig. 2, the lowest beds of the Lower Lias, which are well developed at Owthorpe, a mile and a half away, are only thinly represented at Cotgrave Gorse. This, together with the irregular appearance of the surface of the Sun Bed, suggests that a short break in deposition may have occurred in this locality. The occurrence of the Sun Bed at the top of the Rhætic on Beacon Hill, Newark,[3] about half a mile west of the Coddington trench sections, is also interesting, but the section is now overgrown and it is impossible to compare the succeeding deposits.

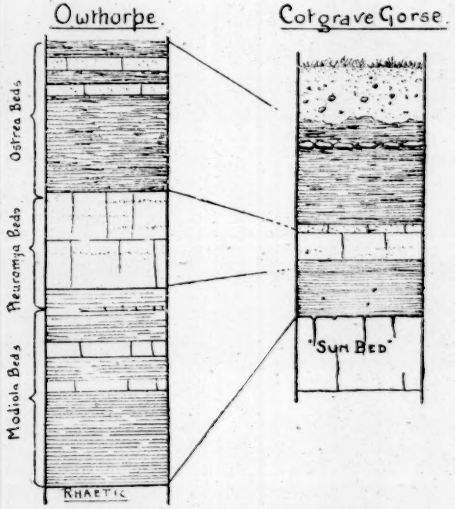


FIG. 2.—Hydraulic Limestones of Owthorpe and Cotgrave Gorse; the lower beds thinning north-westwards.

2. Lower Lias Clays.

Apart from their use in brickmaking, these clays have little economic value, and exposures in this area are rare. It is therefore only possible to give an account of scattered observations, the preservation of which may eventually facilitate a more complete study of the district. Deep borings have shown the thickness of

[1] A. E. Trueman, op. cit., 1915, p. 152.
[2] *Geology of Melton Mowbray* (Mem. Geol. Surv.), 1909, p. 19.
[3] *Geology of South-West Lincolnshire* (Mem. Geol. Surv.), 1885, p. 21.

these clays to be about 700 feet, but yielded insufficient fossil evidence to determine the thickness of the zones.[1]

Bottesford.—Brickyard 400 yards north-east of the church.

Although the brickearth used here is of alluvial origin, Professor Swinnerton in 1915 found in a small exposure at the eastern end of the yard a limestone with *Coroniceras Bucklandi*, which had not previously been found in this area, although it had been recorded in North Lincolnshire.[2] In 1916 the section was as follows:—

	ft.	in.
Grey earthy limestone, yellow outside, with *C. Bucklandi*		6
Blue clay	1	6
Yellow-grey earthy limestone		4
Blue clay	1	0
Blue earthy limestone		4
Clay	2	0

Fossils.

Fish teeth.
Coroniceras Bucklandi, Sow.
Gryphea (?) *arcuata*, Lam.
Hippopodium ponderosum, Sow.
Lima gigantea, Sow.
Modiola sp.
Ostrea liassica, Str.
Pecten sp.
Pleuromya sp.
Echinoid spines.
Pentacrinus cf. *scalaris*, Goldf.
Cytheridea spp.
Glandulina paucicosta, Roem.
Marginulina picta, Terq.

An interesting feature of the fauna is the presence of numerous ostreaform Lamellibranchs, varying in development from the prodissoconch to adult stages.

Sedgebrook.—Brickyard 400 yards north of Sedgebrook Station. The exposure shows the following:—

	Feet.
Soil, etc.	2
Blue clay, weathering yellow, with impersistent ferruginous limestones and shell beds	6

Fossils.

Arnioceras cf. *semicostatum*, Y. & B.
A. cf. *ceras*, Agass.
Belemnites acutus, Mill.
B. cf. *breviformis*, Voltz.
Amberleya elegans, Münst.
Trochus Redcarensis, Tate.
T. sp.
Turbo sp.
Arca sp.
Arcomya hispida, T. & B.
Astarte aff. *striato-sulcata*, Roem.
Gryphea obliqua, Sow.
G. arcuata, Lam.
G. arcuata (a wide variety).
G. cf. *cymbium*, Lam.
Hippopodium ferri, Cross-Ether.
Lima (*Plagiostoma*) *gigantea*, Sow.
L. (*P.*) *punctata*, Sow.
L. (*P.*) aff. *succincta*, Sch.
Limea acuticosta, Münst.
Macromya sp.
Modiola bifasciata, Tate.
Nucula aff. *palmæ*, Sow.
Ostrea goldfussi, Bronn.
O. sp.
Pecten cf. *æqualis*, Qu.
P. calvus, Goldf.
P. lunularis, Roem.
P. cf. *priscus*, Sch.
P. textorius, Sch.
Pholadomya aff. *glabra*, Agass.
Pinna Hartmanni, Ziet.
Serpula sp.
Rhynchonella calcicosta, Qu.
Echinoid spines.
Cytheridea ellipsoidea, Jones.
C. Moorei, Jones.
C. aff. *elongata*, Blake.
Dentalina cf. *funiculosa*, Terq.
D. (?) *pauperata*, d'Orb.
Frondicularia Terquemi, d'Orb.
Lingulina tenera, Borne.
Marginulina picta, Terq.
Vaginulina anomala, Blake.

[1] *Water-supply of Lincolnshire* (Mem. Geol. Surv.), 1904, pp. 63, 101.

[2] By F. M. Burton; see *Geology of Lincoln* (Mem. Geol. Surv.), 1888, p. 19.

The zone is evidently that of *Pentacrinus tuberculatus*, and the horizon near that of the Plungar ironstone. The fauna resembles that recorded by the Rev. J. E. Cross in the ironstones of the "*semicostatus* zone" (*tuberculatus* zone of Oppel) at Scunthorpe, in North Lincolnshire.[1] It is interesting to note the absence at Sedgebrook of all species of *Cardinia*, one of the commonest and most characteristic fossils in the north of the county. *Cardinia* does occur, however, within a few miles of Sedgebrook, near Bottesford and Allington,[2] and this suggests that the horizon seen here is not precisely that of the Scunthorpe ironstone.

The strata between the two horizons just described were penetrated in 1916 by an unsuccessful boring for water, which was made at Plungar, about a quarter of a mile south-west of the church. The section was roughly as follows:—

		Feet.
Ironstone and clay with *Gryphæa*, *Lima*, and *Avicula*	about	4
Dark-grey marl		30
Dark shale with shelly bands		40
Light-blue shale		10
Several beds of fine blue limestone with *C. Bucklandi*		2
Blue shale		6

It is probable that with the exception of the uppermost few feet, all the rocks passed through belong to the *Bucklandi* zone, which apparently has a thickness of more than a hundred feet.

Higher beds were shown by another boring a few yards east of the Stathern Station; it was made in 1916 by Messrs. Le Grand and Sutcliffe, who gave permission to examine the core and supplied some of the following particulars:—

	ft.	in.
Blue-grey clay	69	0
Shell beds and shales. Earthy limestone with *Ostrea*	5	0
Soft dark clay	27	0
Light-grey clay with thin limestone	1	0
Light-blue, hard limestone; *Ostrea*	1	0
Light-blue marl	35	0
Massive limestone	1	6
Black pyritic marl	17	6
Grey sandy marl with Lamellibranchs	2	0
*Grey marl with bands of earthy limestone, with *Ostrea*, *Pecten*, *Avicula inæquivalvis*	29	0
Clay with bands of limestone	26	0
(Boring abandoned; no water reached.)		

The bed indicated * contains an association of fossils which resemble those in the ironstone band at Plungar, and is probably its equivalent. The outcrop of the ironstone can only be traced for two and a half miles south-west of Plungar,[3] and it appears to have a similarly restricted extension towards the south-east, for no indication of it is shown in the boring, the strata passed through consisting almost entirely of clays and shales.

[1] J. E. Cross, "Geology of North-West Lincolnshire": Q.J.G.S., vol. xxxi, p. 123, 1875.

[2] *Geology of South-West Lincolnshire* (Mem. Geol. Surv.), 1885, p. 30.

[3] W. Gibson, *Geology of Melton Mowbray, etc.* (Mem. Geol. Surv.), 1909, p. 33.

Exposures of the clays above the Plungar ironstone are rare, and such as still exist are not very helpful. A brick-pit south of Brant Broughton shows 10 feet of fine-textured sandy clay, with fossils indicating the *oxynotum* zone; another pit near the canal at Woolsthorpe shows similar clays which were thought by the Survey [1] to represent part of the *Jamesoni* zone. A disused brick-pit south-east of Bassingham in 1916 showed the following succession:—

	ft.	in.
Marly clay with *Pleuromya*	1	0
Yellow raggy limestone with *Belemnites*	1	6
Clay	6	0

Such fossils as were found confirmed the Survey's conclusion that these beds should be assigned to the *armatum* zone.[2]

(*To be concluded in the March Number.*)

IV.—On the New Brachiopod Genus, *Liothyrella*, of Thomson.

By J. Wilfrid Jackson, F.G.S., Assistant Keeper, Manchester Museum.

THE new genus, *Liothyrella*, has recently been created by Dr. J. Allan Thomson [3] for the reception of a series of recent and fossil Terebratulids commonly ascribed to the genus *Liothyrina*. The chief characters upon which the genus is founded are the presence of fine radial ribbing on the surface of the shells and the possession of a short, low, thin, mesial septum in the dorsal valve. In the thickness of the shell, *Liothyrella* is said to stand between *Liothyrina* (genotype *L. vitrea*) and *Terebratula, sensu str.*, all three genera being finely punctate. Thomson takes the recent Magellanic species *L. uva* (Brod.) as the genotype of *Liothyrella*, and includes in the same genus *L. uva*, var. *notorcadensis*, Jackson,[4] from Scotia Bay, South Orkneys, and a new species dredged off Tasmania by the Mawson Expedition, as well as two Australian Tertiary species, *Terebratula tateana*, Tenison-Woods, and *T. concentrica* (Hutton). He remarks that "probably also many of the other southern species ascribed to *Liothyrina* will be included here, but the descriptions do not state whether or not a mesial septum is present" (op. cit., p. 44).

The excellent researches made recently by Thomson upon the morphology and classification of the Brachiopoda are to be highly commended, as they have led to some remarkable discoveries being made in connexion with New Zealand Tertiary species. Though agreeing in the main with his conclusions regarding some of the groups with which he has recently dealt, I feel compelled to dissent from him with regard to the proposed division of the *Liothyrinæ* on the lines defined. My own researches, extending over several years and embracing numerous recent and fossil species, have led me to offer the following observations.

[1] A. J. Jukes-Browne, *Geology of South-West Lincolnshire* (Mem. Geol. Surv.), 1885, p. 32.

[2] W. H. Dalton, *Geology of Lincoln* (Mem. Geol. Surv.), 1888, p. 21.

[3] Trans. N. Zeal. Inst., vol. xlviii (1915), p. 44, 1916.

[4] Jackson, "The Brachiopoda of the Scottish National Antarctic Expedition": Trans. Roy. Soc. Edin., vol. xlviii, pt. ii (No. 19), p. 375, pl. i, figs. 1–3, 1912.

With regard to the mesial dorsal septum, though this appears to be occasionally absent in the genotype of *Liothyrina*, viz. *L. vitrea*, it is present in two of my specimens from the Mediterranean as a slight, but distinct, ridge between the muscle scars. One shell is of large size with a thick test, but otherwise agrees with normal *L. vitrea*. Fine radial striæ are present on all my specimens. The radial striæ of *L. vitrea* was noted by Fischer and Oehlert in 1891,[1] as well as the thickening of the test and the presence of a mesial septum in thick shells. *L. vitrea* thus possesses the three essential characters upon which the new genus *Liothyrella* is founded.

Liothyrina cubensis (Pourt.), another northern species, often regarded as merely a form of *Liothyrina sphenoidea* (Phil.), supplies us with contributory evidence. In one of my specimens from the coast of Mexico, which agrees exactly with Davidson's[2] and Blochmann's[3] figures, the radial striæ are present, but are very indistinct; there is also a slight thread-like ridge between the muscle scars in the dorsal valve. In two specimens of the same species from Porto Rico (100 fathoms) the radial striæ and slight mesial septum are also present, the latter showing through the shell.

In 1908 Blochmann (op. cit., pp. 612–25) divided the genus *Liothyrina* in two groups according to the presence or absence of certain calcareous spicules at the base of the cirri (*Cirrensockeln*). The first group, that in which the spicules are present, is widely distributed, and includes *L. affinis*, Calc. (Mediterranean, Azores, etc., and possibly West Indies), *L. arctica*, Friele (Iceland and Greenland), *L. antarctica*, Blochmann (Antarctica), *L. winteri*, Blochmann (St. Paul, Indian Ocean), *L. uva*, Brod. (Magellanic region and Western American coast to Mexico). With these he provisionally included *L. davidsoni*, Adams, *L. clarkeana*, Dall, *L. fulva*, Blochmann, and *L. moseleyi*, Davidson. The second group, without the basal spicules, comprises *L. vitrea* (Born), *L. sphenoidea*, Philippi, *L. cubensis*, Pourt., *L. bartletti*, Dall, and *L. stearnsi*, Dall & Pilsbry. This group occurs chiefly in the Mediterranean Sea and Atlantic Ocean, but one species (*L. stearnsi*) is found off the east coast of Japan. Another species (*L. cernica*, Crosse), found at Mauritius, is also referred to this group, though neither spiculæ nor brachidium are known. The figures of *L. bartletti* and *L. stearnsi* given by Blochmann (op. cit., pl. xxxix, figs. 27, 29) distinctly show that each possesses a dorsal mesial septum.

Since Blochmann made this division other forms have been described, viz. *L. uva*, var. *notorcadensis*, Jackson (South Orkneys, South Georgia, and Western Antarctic), and *L. blochmanni*, Jackson (Antarctica).[4] The former appears to belong to the first group, the latter to the second group. Further examples of *L. fulva*, from

[1] *Exped. Scient. du "Travailleur et du Talisman," 1880–3": Brachiopodes*, Paris, 1891, pp. 51, 57.

[2] "A Monograph of Recent Brachiopoda," pt. i: Trans. Linn. Soc., ser. ii, Zool., vol. iv, pt. i, pl. ii, figs. 19–19*b*, 1886.

[3] "Zur Systematik und geographischen Verbreitung der Brachiopoden": Zeit. für wissen. Zool., Bd. xc, pl. xxxviii, figs. 21–21*c*, 1908.

[4] Jackson, op. cit., pp. 375, 378.

Tasmanian waters, show that it is now to be relegated to the second group, as this species has no cirri bases.[1] I had independently arrived at a similar conclusion from the construction of its loop and hinge-processes, details of which are given on a later page.

Of the first group I have only been able to study actual specimens of *L. uva* and its var., and *L. antarctica*, as well as some recent and fossil specimens of *L. affinis*—the recent from off the Algerian coast, the fossil from the Pliocene of South Italy and Sicily.

L. uva and *L. antarctica* have extremely fine radiating striæ on the surface of the shells, and both possess a slight mesial dorsal septum; this is at times somewhat more noticeable than in *L. vitrea* and *L. cubensis*, though not to any great degree. *L. uva*, var. *notorcadensis*, and *L. blochmanni* show similar features (see Jackson, op. cit., 1912).

On *L. affinis* from Algeria the radii are clearly present and wide apart; there is also a fine mesial septum in the umbonal cavity of the dorsal valve; the shells are rounded in outline. Of the fossil examples, two forms are present—elongate-oval (= typical *affinis*) and rounded (cf. *arctica*)—from the two localities, viz. Calabria, S. Italy, and Messina, Sicily. These two forms are too near each other to warrant separate distinction. The radial striæ on both forms are very indistinct, but they can sometimes be made clearer by slightly moistening the surface of the valves. In type of cardinalia they agree with the Algerian *L. affinis*, but the presence of a mesial septum is a little uncertain.

The presence or absence of radial striation on Terebratulids should form an interesting study. The following are a few of the occurrences which have come under my notice. Of Jurassic *Terebratulæ*, *T. phillipsi*, from the Inferior Oolite of Broadwindsor, has incipient radii, especially on the anterior portions of the valves. On *T. intermedia*, from the Cornbrash of Kidlington, the radii are likewise present on the anterior and lateral portions of the shell. Among Cretaceous forms, radial striation is fairly strong and wavy all over the shell in *T. sella* from the Lower Greensand of Hythe and Wellingborough. *T. depressa*, var. *cyrta*, from the Lower Greensand of Upware, also shows striæ radiating from the beak: the dorsal valve of this form has a mesial septum. On several of the Chalk species presumed to belong to *Liothyrina*, e.g. *T. carnea*, *T. semiglobosa*, etc., the striæ can also be detected. They are fairly wide apart and appear to be just below the outer layer of the test: they are very indistinct and can only be seen on holding the shell in a particular position. My observations have been made on *T. carnea* from Gravesend, Norwich, Caburn, and Maestricht, and on *T. semiglobosa* from Lewes and other localities. *T. carnea* possesses a distinct mesial dorsal septum. A specimen of *T. obesa*, from "Chalk, Sussex (?)", in my collection, is also radially ribbed, especially on the flanks. The radii extend from near the beak to the anterior border, and are closer together and more distinct than in *T. carnea*,

[1] Blochmann, "Some Australian Brachiopods": Papers and Proc. Roy. Soc. Tasm. for 1913 (1914), pp. 112, etc.

etc. This feature is clearly shown in Davidson's figures,[1] and is referred to in the text (p. 54). It resembles that seen on recent *Dyscoliæ*, especially *D. crossei*, Dav.

Among the Tertiary species, *T. bisinuata*, from the London Clay, is a good example. On my specimens from near Fareham the radii are fairly wide apart and more noticeable on the side areas. The dorsal valves show a thin, low, thread-like mesial septum, superposed on a flat platform separating large pear-shaped muscular impressions. In type of cardinalia this species is similar to the well-known Crag *Terebratulæ*, which also show the striation very distinctly, especially on the lateral parts of the valves. These, however, have no mesial dorsal septum. They are presumed to be true *Terebratulæ*. The cardinalia of these Crag forms and of *T. bisinuata*, of the London Clay, have never been properly described. The type is a peculiar one: there is a prominent semicircular, or semi-ovate, cardinal process standing out from the apex of the valve like a shelf; the socket-ridges, bounding the dental sockets, are prominent and diverge from the apex, or at least from the corners of the cardinal process; their inner sides descend sharply and touch the floor of the valve posteriorly; the plates then curve upwards (ventrally) to the well-marked crural bases, the posterior extremities of which are often clearly separated from the apex by a small space. On the inner sides of the strong ridges forming the crural bases, thin, narrow, plates are given off, these plates being free from contact with the valve posteriorly and well separated from each other mesially.[2] In some of the dwarf Crag *Terebratulæ* these inner hinge-plates are much broader and touch each other in the median line at their posterior ends. While dealing with the Crag *Terebratulæ* it may be of interest to refer to an allied form occurring in the Pliocene of Calabria, S. Italy. This form, usually recorded as *T. grandis* or *T. scillæ*, has a type of cardinalia similar to the Crag form, except that the inner hinge-plates are very rudimentary. Of the five examples cleaned out and examined (these being of equal size to the Crag examples dealt with), all exhibit the same features: but in one or two there is a thread-like mesial septum.

The above-mentioned ridges (crural bases) with their attached inner hinge-plates clearly distinguish this type of cardinalia from that of *Liothyrina*. No evidence of these inner plates is present in any recent *Liothyrinæ*; nor are the crural bases so well defined.

The ascription of the Chalk species to the genus *Liothyrina* (mainly, I believe, on account of the grooves for the attachment of the pallial sinuses showing through the test) is open to some question. Their general external appearance, small foramen, and the massiveness of the cardinalia suggest that they might be terminal members of a distinct genetic group. The following remarks are based mainly on a study of several valves of *T. carnea* which have been developed to show interior details. The most

[1] *Monog. Brit. Cret. Brach.* (Pal. Soc.), 1854, pl. v, figs. 13–16.

[2] For a good figure of the cardinalia, see Davidson, *Monog. Brit. Tert. Brach.* (Pal. Soc.), 1852, pl. ii, fig. 3.

notable feature of this species is the excessive thickening of the hinge-processes and muscular fulcra generally. This fact renders it a somewhat difficult matter to define the type of cardinalia. I fortunately possess one specimen in which the calcification has not progressed so far as usual: this shows both cardinalia and brachidium. The crural bases in this are well-defined and consist of fairly broad plates set almost vertically to the slight hinge-plates uniting them with the high-standing socket-ridges. The hinge-plates unite along the middle line of the crural bases, the latter having a well-defined ventral and dorsal edge. I have seen no junction like this in any recent *Liothyrina*; nor is it present in the Crag or London Clay *Terebratulæ*. There is a prominent cardinal process at the apex of the valve; also a thin hair-like mesial septum in the umbonal cavity. Both the cardinal process and mesial septum become more definite in the thickened specimens. The crura are broad and short; the descending branches and transverse band of the loop are also broad, and the latter is sharply bent ventralwards in the middle. The junction of the descending branches with the transverse band is sharply angulated. Figures of the interior of *T. carnea* are given by both Davidson [1] and Quenstedt.[2]

Before proceeding it might here be appropriate to point out that the brachidium of the Crag *Terebratulæ* differs from that of *T. carnea* in being relatively wider with a narrow transverse band not sharply bent ventrally, and in having much sharper points at the extremities of the descending branches. It has also longer crural points.[3] In general characters it resembles that of the recent *L. uva*, but not that of *L. vitrea*.[4]

The cardinalia and brachidium in recent *Liothyrinæ* exhibit some interesting features. The type seen in *L. uva* and closely allied forms differs somewhat from that of the genotype, *L. vitrea*, and very materially from that of *L. stearnsi* or *L. bartletti*. The extremes are clearly seen in Blochmann's figures (op. cit., 1908, pl. xxxix). In *L. uva* the whole structure is of a short triangular form, and the transverse band of the loop is very narrow. The junction of the descending branches with the transverse band is sharply pointed. The crural points are close in. Between the socket-ridges and the ill-defined crural bases is a narrow curved plate. There is a thin mesial septum. In *L. stearnsi*, on the other hand, the structure consists of long, almost parallel, descending processes, and the transverse band is very broad; it is also sharply bent ventralwards in the middle. The characteristics of *L. stearnsi* are taken from Blochmann's figure (op. cit., 1908, pl. xxxix, fig. 29). *L. vitrea* and some others appear to agree closely with this form. In general the crural bases, which are not very marked, are well separated

[1] *Monog. Brit. Cret. Brach.* (Pal. Soc.), 1854, pl. viii, figs. 2, 2*a*.

[2] *Petrefactenkunde Deutsch., II, Brachiopoden*, Leipzig, 1871, pl. xlviii, fig. 42.

[3] This is based upon the figure given by Davidson, *Suppl. Tert. Brach.* (Pal. Soc.), 1874, pl. ii, fig 1, and upon imperfect specimens of my own.

[4] The ovate outline and broad dorsal uniplication of the Crag shells also show greater affinity with *L. uva*.

from the socket-ridges by flat, or slightly concave, thin plates.[1] As stated previously, a thin mesial septum is present in some of these forms.

These two types appear to characterize two distinct groups of species, the members of which possess certain common features. The first group comprises broadly dorsally uniplicate oval shells with a rounded front, as, for example, *L. uva*, and var. *notorcadensis* and *L. antarctica*, a group which, according to Blochmann, possesses basal spicules in the cirri; while the second group comprises shells with a somewhat truncated front, and, in some cases, broad dorsal uniplication, such as *L. vitrea*, *L. sphenoidea*, *L. cubensis*, *L. bartletti*, and *L. stearnsi*—a group without the basal spicules. The shells of this group are, as a rule, much larger than those of the first group.

By adopting the principle of classification by means of the construction of the brachidium and cardinalia I had already arrived at the conclusion that two such groups existed. It is interesting, therefore, to find that this is borne out with regard to spiculation. We have thus a standard which is of some service in the classification of fossil forms, the question of spiculation being, of course, impracticable for fossils. It was on these grounds that I placed *L. fulva*, which has a broad transverse indented band to its loop,[2] in the second, or *L. vitrea*, group. This has now happily been confirmed by Blochmann's researches with regard to spiculation. From his figures (op. cit., 1914, pl. x, figs. 1–4) this species appears to be non-plicate with a tendency towards a truncated front.

Other species of recent *Liothyrinæ* still await further examination. *L. moseleyi*, apparently a lenticular species, has a broad indented transverse band to its loop.[3] Its spiculation is, as yet, unknown, but from the circumstance that a broad band appears to go with weak spiculation, it is not unreasonable to assume that it will be found to be of the *L. vitrea* type. The interior details of *L. davidsoni* and *L. clarkeana* are too scanty for diagnostic purposes. The Antarctic *L. blochmanni* has a type of cardinalia and brachidium quite distinct from that of *L. uva* or *L. antarctica*, it being nearer that of *L. sphenoidea*.[4] Its spiculation appears to be of a weak character, and, therefore, more like that of the *L. vitrea* series, with which I have placed it.

From the above observations it has been seen that the presence or absence of radial striation, or of a mesial dorsal septum, does not assist materially in the separation of Terebratulids into generic groups. On the other hand, the character of the brachidium and especially the cardinalia, which owing to their rôle as supports for important elements of the muscular system, and consequently

[1] See Blochmann, op. cit., 1908, pl. xxxix; also Fischer & Oehlert, op. cit., 1891, pl. iii (for *L. vitrea* and *L. sphenoidea*).

[2] See Blochmann, op. cit., 1908, pl. xxxix, fig. 26; and Blochmann, op. cit., 1914, pl. x, figs. 5, 6.

[3] See Blochmann, *Wissen. Ergeb. der Schwed. S.-P. Exped.*, 1901–3, Bd. vi, Lief. vii, pl. i, fig. 14, 1912.

[4] Compare Jackson, op. cit., 1912, pl. i, fig. 6, with Blochmann, op. cit., 1908, pl. xxxix, fig. 23*a*.

subject to more modification, may provide more certain ground for distinguishing the various groups of related species.

On these grounds it has been clearly proved that the Chalk species (*T. carnea*, etc.) are not to be referred to *Liothyrina*, but probably belong to a separate group entirely; and that the Crag and other Tertiary *Terebratulæ* form another distinct series. If we accept the evidence as trustworthy in these cases, we seem compelled to acknowledge the new genus *Liothyrella*, recently created by Thomson, subject to the emendations dealt with in this paper.

V.—The Kaolin Veins.

By Lieutenant J. B. Scrivenor, M.A., F.G.S.

KAOLIN occurs abundantly in the Federated Malay States in connexion with granite, and is certainly formed on a large scale by weathering. The purest kaolin in large quantity, however, is found as veins in clay above limestone at Gopeng and elsewhere in Kinta, and in quartzite and shales near Tanjong Malim and Kerling. The purity of these veins and the information obtained about those in Kinta when traced down to limestone, lead to interesting considerations about their origin, and the nature of the material in the limestone is a matter of importance in connexion with the possibility of establishing a kaolin industry.

The form of the Gopeng veins has been described elsewhere, and in the early edition of the Kinta publication, illustrations were given showing the junction of the kaolin and clay. In *A Handbook to the Collection of Kaolin, China-clay, and China-stone in the Museum of Practical Geology*, 1914, by Mr. J. A. Howe, some notes were contributed and a vein at Kramat Pulai figured (p. 102). In these notes I stated, "No fresh felspar or partially decomposed felspar has been detected as yet in these veins. This might be taken as evidence of the kaolin having been kaolin *ab origine* and not an alteration product, but it is not conclusive evidence against a pneumatolytic origin." Since writing this, residues from many samples of kaolins treated with acid have been examined, and among them some from the Gopeng veins. The minerals unattacked are mica, quartz, tourmaline, and small grains, not abundant, that may be partially decomposed felspar. From kaolin near Kerling (Selangor) sand lighter than 2·8 sp.g. was separated, and in it are a few grains that may be partially decomposed felspar. In the field I have not seen any felspar in these veins, but in places where quartz is abundant I have noticed a trace of graphic structure, as though quartz and felspar had once been intergrown.

A pink mica is present in these veins and has been described as lepidolite. A specimen of similar mica from Chanderiang gave a strong lithia reaction with the spectroscope, but one specimen from Gopeng proves on analysis by Mr. C. Salter, to be muscovite with ·86 per cent of manganese. It is possible, therefore, that much of the pink mica may be a manganese mica.

Tin-ore is believed to occur in the Gopeng veins, and is known to occur in the Kerling veins, in fact they are worked for tin.

Kaolin from the Kerling veins was washed and afforded deep brown cassiterite and mica. No tourmaline was found in the concentrate, nor was it seen in the field.

Lately information has been obtained at Gopeng and Pulai about these veins in contact with the limestone. At Kramat Pulai a pinnacle of limestone was exposed in January, 1916, close to a kaolin vein. In the limestone was a granitic vein about 2 feet wide, bordered by a pale-green massive mineral with a slightly greasy feel. The granitic rock contains felspar, sometimes in porphyritic crystals. Sections show that it consists of quartz, orthoclase, and plagioclase, the last being abundant. One specimen is finely veined by a serpentinous mineral that is probably the pale-green mineral just mentioned. They show a little tourmaline and some altered biotite, and also micaceous aggregates suggesting pinite pseudomorphs of cordierite. Near by, in the same pinnacle, are thin veins of "mountain-leather" or asbestos of the serpentine variety (magnesium silicate), together with purple quartz. No vein of kaolin was seen in the limestone.

On the Kinta Tin Mines, Ltd., large quantities of the pale-green massive mineral occur in juxtaposition to limestone. It is not as greasy to the touch as steatite, but resembles it, and partial analysis showed that it consists of magnesium and aluminium silicate. It is therefore one of the ill-defined minerals allied to serpentine, and differs from the kaolin in having magnesium present in addition.

The same mineral occurs associated with kaolin in two of the open-case mines on the Gopeng Consolidated land. In that on the north of and close to the Khota Bahru Road there were found with it fairly large crystals of a reddish mica which contained no lithium, and one specimen was found consisting of this mica, quartz, and andalusite. The kaolin, close to where this specimen was taken, contained dendritic markings of manganese oxide, and a small pocket was found in the kaolin of black clay consisting of manganese and iron oxides. Its presence was puzzling until it was discovered that some at least of the pink mica at Gopeng is a manganese mica.

In a big mine south of the Khota Bahru Road there was a good section in March, 1916, of the magnesium-aluminium silicate in the limestone. It formed a distinct vein about 2 feet across. Close by was kaolin with quartz and white mica. Near by here pockets of the same mineral were found in pure white kaolin.

In the above instances there is no evidence of the kaolin continuing in the limestone as kaolin. It changes to something else, and the green magnesium-aluminium silicate suggests a reaction between the magma that supplied the kaolin and magnesium in the limestone. The way in which the granitic vein on Kramat Pulai is bordered and veined by this mineral favours this view. On the North Tambun Mine, however, I have seen a very thin kaolin vein in limestone, and many years ago I saw a similar thing at Tambun. However, there is now strong evidence that the bigger veins do not go down into the limestone as kaolin, and one naturally wants to know how they were formed, and the first explanation that presents itself is that they are veins that were

originally chiefly felspar, which has been altered to kaolin by deep-seated changes during the last stages of the cooling of the granitic magma. If that is incorrect, then the kaolin must have been kaolin from the moment it consolidated, or it must have been formed in recent times by weathering. With regard to this question of the origin of kaolin, there is a marked difference of opinion between British and American geologists. It is difficult to get one of the former who has not visited the Tropics to allow that kaolin can be formed by weathering at all. On the other hand, Lindgren, in his *Mineral Deposits*, p. 305, writes as follows: "The idea that the mineral may form by pneumatolysis, or the action of water or gases liberated at high temperature from igneous magmas, is assuredly untenable; a strongly hydrous mineral, parting with its water at the comparatively low temperatures of 300 to 400° C., could not possibly originate in the presence of such minerals as topaz and tourmaline." Lindgren favours an opinion that certain china-clay deposits in Cornwall, generally regarded as of pneumatolytic origin, were formed by the weathering of sericitic granite, the sericite being due to previous alteration by thermal waters. It is not necessary, however, to postulate that kaolin was formed at the same time as topaz and tourmaline. It may have been formed afterwards when the temperature was lower; and, as kaolin formed by weathering from the granite in the Malay States contains much of recognizable felspar, unattacked or only partially attacked, the purity of the Gopeng and other kaolin veins might be cited as pointing to a different mode of origin. The objections to its having been kaolin from the beginning are the same as those brought forward by Lindgren to pneumatolysis, and even stronger when applied to this idea and more applicable. Moreover, there is some, although not good, evidence of felspar being present in small quantities. On the other hand, if the kaolin is due to pneumatolytic action, why do the large veins stop when the limestone is reached? The granitic vein on Kramat Pulai points to pneumatolysis, if it took place at all, having been confined to rocks above the limestone, and makes weathering seem less impossible as a mode of origin than I once thought. It is to be hoped that future excavations on the tin-mines will give some decisive information one way or the other.

Specimens of kaolinite formed by weathering from felspar in the Main Range granite at the Gap, Pahang, and specimens of kaolinite from Gopeng and Kerling, have been compared with kaolinite from a kaolinized felspar crystal in the Dartmoor granite. The refractive index is about the same in all cases. The double refraction is more marked in the Gap kaolin than in the others. In the Gopeng specimen fan-shaped and vermicular aggregates of plates are common. Vermicular aggregates also occur in the Kerling specimen. The Gap kaolinite forms some aggregates of parallel plates, and the kaolinite from the Dartmoor specimen forms irregular flakes only.

At the same time specimens of "Lenzinite" and "Glagerite", allied hydrous silicates of alumina, were examined. The Lenzinite

had a lower refractive index than any of the above; the double refraction was hardly noticeable and it consisted of very fine flakes and minute vermicular aggregates. The Glagerite had a higher refractive index than any of the other specimens.

The examination of these specimens was undertaken in the hope of arriving at some definite conclusion about the origin of the kaolin veins in this country, but it cannot be said that one has been attained.

NOTICES OF MEMOIRS.

I.—Martin Simpson, a Yorkshire Geologist (1800–92).

AT the annual meeting of the Yorkshire Geological Society, held at Leeds on December 12, Mr. T. Sheppard, M.Sc., F.G.S., read a paper on "Martin Simpson and his Work".

Martin Simpson was born at Whitby in 1800, and died in 1892. He spent most of his life in the Whitby district, and for over half a century had charge of the valuable Geological Collection in the Museum there, though for a short period he was Curator of the Yorkshire Geological Society's Collection, now in the Museum at Leeds. He was one of the pioneer workers among the Yorkshire Liassic rocks, and considering the early date of his researches the enormous amount of information he accumulated was remarkable, and his methods of research had a surprisingly modern air. He was the author of a number of geological memoirs, most of which are now exceedingly scarce.

Mr. Sheppard showed a complete series of these works, which he had collected, the most important being a memoir on the *Ammonites of the Yorkshire Lias*, which was long since said to be so rare that only one copy was known. Another work, published when the author was 84 years of age, was *The Fossils of the Yorkshire Lias*, in which no fewer than 743 species were enumerated and more or less described. Simpson measured with a foot-rule the thickness of the Lias beds north and south of Whitby, taking special note of the fossils in each bed, a very early example of zonal collecting.

II.—The Mineral Resources of the British Empire.

FOR the second year in succession the Swiney lectures were given by Dr. J. S. Flett, F.R.S. As already announced in the Geological Magazine, the subject chosen was "The Mineral Resources of the British Empire". By means of a judicious mixture of statistics, engineering, and geology Dr. Flett succeeded in giving a remarkably interesting, though necessarily condensed, account of a very large subject. It was shown that in the case of some minerals, such as tin, nickel, and diamonds, the British Empire is still the greatest producer, while in other instances its former pre-eminence has passed into foreign hands, especially into those of the United States and Germany. It is evident that in the immediate future Canada will be an important producer of many minerals, besides oil and gas on a large scale. The mines of Sudbury, Cobalt, and Porcupine were dealt with by the lecturer in some

detail, and a great future was predicted for the metal cobalt, which in some ways is superior to nickel. The production of tungsten ores has been greatly stimulated by the War, and many new sources have been discovered. Molybdenum is also rapidly increasing in importance for the same reason. The gold production of South Africa has now reached the enormous value of nearly forty million pounds sterling per annum.

The lectures, which were illustrated by a large number of excellent lantern slides, were listened to by large and appreciative audiences, and must be regarded as highly successful.

III.—The Age of the Bolivian Andes.

IN 1915 Professors Singewald and Benjamin L. Miller collected from rocks of hitherto undetermined age in the copper district of Corocoro fossil plants of the same flora as that previously known from the silver district of Potosi, whence also they made collections. These have been described by Professor E. W. Berry (Proc. U.S. Nat. Mus., vol. liv, pp. 103–64, pls. xv–xviii, October, 1917) and the types and figured specimens presented to the United States National Museum. The age of the flora is determined as Pliocene, whence it follows that the major elevation of the Eastern Andes of Bolivia and the high plateau took place in the late Pliocene and throughout the Pleistocene, and that the extensive mineralization of the region is of equally late geological age. A Brachiopod, *Discinisca singewaldi*, found at 13,500 feet above sea-level, and described by Professor Schuchert in the same paper, similarly proves an elevation of at least that amount since Miocene times.

IV.—West Australian Chalk Foraminifera.

THE fauna of the Gingin Chalk (= Albian to Cenomanian) was made known by the researches of Robert Etheridge, jun. (Bull. Geol. Surv. W. Australia, No. 55, 1913), and its Foraminiferal contents listed by Howchin (Rep. Adelaide Meeting Austr. Assoc., September, 1893). Since then Frederick Chapman has been working on the deposit, and has now produced a monograph on the Foraminifera and Ostracoda (Bull., No. 72, 1917). A mere glance at Chapman's careful drawings shows the completely Upper Cretaceous nature of the deposit and the remarkable agreement of the fauna with the English equivalents. Eighty-one pages, of which 14 are devoted to illustrations (plates); 134 species of Foraminifera, 16 of Ostracoda.

REVIEWS.

I.—James Geikie, the Man and the Geologist. By Marion I. Newbigin and J. S. Flett. pp. xi + 227, with four portraits. Edinburgh: Oliver & Boyd, 1917. Price 7*s.* 6*d.*

THIS charmingly written book is divided into two distinct parts. The first, by Miss Newbigin, deals with James Geikie's life from the biographical standpoint, while in the second part Dr. Flett

gives an appreciation of his scientific work. The first part sketches in a somewhat brief but thoroughly interesting way the career of one of the best-known British geologists of the second half of the nineteenth century, a man who had a great influence on the trend of geological thought in this country and who was mainly responsible for building up a highly successful school of geology in the University of Edinburgh. The authoress deals in a sympathetic way with Professor Geikie's private life, with his career on the Geological Survey, and with the part he played in the scientific and social life of Scotland in his time. Although primarily an investigator and field geologist, Professor Geikie ultimately became a great teacher and his books are known everywhere for their breadth of view, lucidity, and charm of style. Perhaps, however, his success as a teacher and on the Survey was still more owing to his personality and to his power of communicating some of his own enthusiasm to his fellow-workers and pupils.

As a geologist James Geikie was a specialist in two directions: he was always deeply interested in the origin of physical and structural features, and in his teaching and writings he endeavoured to draw out the connexion between topography and geological structure. But his name will always be indissolubly connected with the study of glaciation. In the second part of this book Dr. Flett has given us an admirable and impartial summary of his work on this thorny subject. The glacial controversy has been a long one, comprising several distinct phases; even now it seems almost as far as ever from an end. The life of James Geikie may in a certain sense be regarded as an impersonation of the history of glaciology. When his work began the submergence theory was dominant, though soon to be replaced by the land-ice conception. In this change of view his own work played a great part. The course of evolution in this respect may be traced in the successive editions of his book, *The Great Ice Age*. Some twenty years ago land-ice appeared to hold almost undisputed possession of the field, although some notable geological authorities have always questioned its applicability to districts such as central and eastern England, far from any system of mountains. However, of late years a certain number of awkward facts have cropped up and the still small voice of doubt is again making itself heard in the ears of some of the younger generation; at any rate, it is clear that the time has not yet arrived for a definite decision, and it would be well to suspend judgment for a while.

Another phase of the glacial controversy relates to the occurrence of periods of milder climate between successive glaciations. It is with this part of the subject that Professor Geikie was always most closely connected. He will ever be remembered as the apostle of interglacial periods. In his later writings he maintained a succession of six separate glaciations with temperate periods between. In this respect his views agree closely with those of many Continental and American authorities, and, although he did not at the time receive much support in this country, the trend of recent work has undoubtedly been unfavourable to the hypothesis of a single advance and retreat of the ice, which at one time was the orthodox view.

This is impossible to reconcile with the results of the examination of peat-mosses and Arctic plant-beds in many parts of the British Isles, and still more with the brilliant discoveries of recent years in regard to the stages of palæolithic culture and their relation to the Pleistocene deposits. It is too early as yet to pronounce any decided opinion on this subject, but, as Dr. Flett points out, there are signs of a very decided reaction in this respect. If Professor Geikie went too far in one direction, it is certain that his opponents went too far in the other. The subject is a peculiarly difficult one, and it is evident that long and patient investigation is still needed before a final settlement can be reached. It will be conceded by all, whatever may be their personal predilections, that the life-work of James Geikie played a leading part in the unravelling of this tangled skein, and the authors of this book are to be congratulated on having given a clear picture of a great man and a great geologist.

R. H. R.

II.—Fossil Echini of the Panama Canal Zone and Costa Rica. By Robert Tracy Jackson. Proc. U.S. Nat. Mus., vol. liii, pp. 489–501, pls. lxii–lxviii.

THIS short and lavishly illustrated paper provides an account of the Echinoids collected from the Oligocene-Miocene rocks excavated during the making of the Panama Canal. The fauna thus displayed is of a somewhat restricted, but characteristically American, type. No Regular Echinoids are recorded, and the species described belong to four genera only of Irregular forms. The two species of *Clypeaster* (of which one, *C. gatuni*, is new) call for no special comment. The three species of *Encope* (*E. annectans*, *E. platytata*, and *E. megatrema*, all new) exhibit features of exceptional interest, to which reference will be made below. The solitary *Echinolampas* is a well-known West Indian form. Of the three species of *Schizaster*, two (*S. cristatus* and *S. panamensis*) are new, but their preservation is very imperfect.

The genus *Encope* includes an extensive series of Scutelliform Clypeastroids, characterized by marginal slits on the ambulacra, and a solitary lunule perforating the posterior interambulacrum about midway between the apex and the ambitus. This quality may be considered as intermediate between that of *Scutella*, in which there is no lunule and hardly any development of marginal slits, and that of *Mellita*, in which the interradial lunule is present, while the marginal slits have become distally enclosed so as to produce ambulacral lunules. The ontogeny of the latter genus shows that the ambulacral lunules are developed from slits or notches around which the test spreads in later growth-stages, but that the interradial lunule is formed by resorption of the test, and is thus a real perforation. (There is one species of *Mellita* in which all the lunules have the latter character, but this is quite exceptional.)

In *Encope annectans*, described in the paper under review, the marginal (ambulacral) slits are in the stage of embayment normal for species from the horizon (? Burdigalian), but there is no interradial

lunule, properly speaking. Instead, there are two short, narrow grooves indented into the test, one on the adapical surface and one immediately below on the adoral surface by the periproct. The appearance is as if the specimens were wax models which had been pinched by a hot pair of fine forceps. The lunule is thus in this species "caught in the act" of developing by resorption. There is no question of this being an ontogenetic stage of some more ordinary species, for the type is 86 mm. long, and another specimen 93 mm. We have here a peculiarly perfect illustration of the interrelation between phylogeny and ontogeny.

But *Encope annectans* must be a specially retarded or atavistic species, for side by side with it, in the same district and at the same horizon, lived *E. megatrema*, in which the interradial lunule is gigantic when compared with that usual in the genus. The great triangular perforation occupies a large part of what should have been the posterior interambulacrum, comparable (when viewed from the adapical surface) with the large periproct of such a genus as *Pileus*. *E. megatrema* represents a high-water mark of lunule-specialization that has not been attained since. Thus the period of the Gatun formation in Central America marks the childhood of the *Encope*-stock, and the two species here discussed represent respectively the backward and precocious members of the family. Students of phylogeny will welcome this reminder that it is particularly characteristic of youth to run to extremes, and it is this faculty which makes children so fascinating, be they of Holocene or Oligocene date.

H. L. H.

III.—Volcanic Studies in Many Lands (Second Series),[1] being Reproductions of Photographs taken by the Author. By Tempest Anderson, M.D., D.Sc., etc.; Text by Professor T. G. Bonney, Sc.D., F.R.S., etc. London: John Murray, 1917. 15*s.* net.

ALL geologists who remember Dr. Tempest Anderson's first book of photographs of volcanic phenomena will welcome the publication of a second series which has been undertaken by Professor Bonney under the above title. The work entailed in collecting and arranging the views here reproduced must have been considerable, since many of them deal with little-known districts, and as some in addition were taken on Dr. Anderson's last journey, from which unfortunately he never returned, the exact localities of many of

[1] The first part of Dr. Tempest Anderson's *Volcanic Studies in Many Lands* appeared in 1903, and was reviewed in the Geological Magazine for that year by Mr. Hudleston, pp. 160–4. Dr. Tempest Anderson, who spent many years in visiting and photographing active and extinct volcanoes in almost every part of the globe, died on his return voyage from the Philippine Islands, August 26, 1913 (see Obituary, Geol. Mag., Oct. 1913, pp. 478–9). By his will he left £50,000 to the Yorkshire Philosophical Society, of which he had always been a generous supporter; he also added £25,000 to the Percy Sladen Memorial Fund, endowed by his sister in 1904 (see Geol. Mag., Feb. 1914, p. 96).

them were rather doubtful owing to the fact that the notes which he left were often very brief. However, Professor Bonney has done his work well and has, from the material which he found, built up very interesting accounts of some rather imperfectly known volcanic regions.

The book is prefaced by a short life of the author by his friend Mr. G. Yeld, and the chapters immediately following this deal with European volcanoes, and illustrations are given of Vesuvius, Etna, and Stromboli, the latter in eruption; one illustration shows a curious oval-shaped detached smoke cloud floating away from the summit of Etna. The following chapters deal with a second visit to Martinique and St. Vincent, and photographs are reproduced of the returning vegetation on these volcanoes, and also of the surface of the ash deposits formed in the eruption of 1902, showing the effect of denudation on the loose material. In 1906 Dr. Anderson visited Mexico to attend a meeting of the International Geological Congress and endeavoured to obtain photographs of the volcanoes of that country. Owing to the difficulties of travel, not so much was accomplished as was hoped, but photographs were obtained of some of the principal peaks, the most striking being those of Iztaccihuatl and Colima.

From here Dr. Anderson went on to Guatemala. The volcanoes of this country form a row of cones averaging from 10,000 to 12,000 feet in height, roughly parallel with the Pacific coast. They are situated along the edge of a hilly platform about 5,000 feet high, which rises abruptly from the sea, so that, from a passing ship, they may be seen to the full advantage. Their activity is rather intermittent, but eruptions, when they do occur, are generally violent; the ejected material is chiefly fragmentary, lava being very rare.

The most important cones are Cerro Quemado, Atitlan, and Santa Maria. The first, except for a small eruption in 1891, has been quiet since 1785, when it discharged large quantities of lava which must have been very viscous, as the flows often terminate with vertical walls as much as 100 feet in height. Some very fine "bread-crust" bombs were seen here, one of which is shown in a photograph. Atitlan, 11,570 feet high, is 35 miles south-east of Cerro Quemado. Dr. Anderson ascended the mountain, but found on the summit only a very ill-defined crater, with a few fumaroles. The mountain looks down on to a lake twenty miles in length, which from its shape seems to have been a volcanic crater. The third mountain, Santa Maria, which lies a few miles south of Cerro Quemado, is a very regularly shaped ash cone. Prior to 1902 it was supposed to be extinct, but in that year a great lateral outburst occurred which shattered the northern slopes of the cone and produced a new subsidiary crater on a small shelf 6,000 feet above sea-level. The new crater was oval in shape, about three-quarters of a mile long, with its major axis parallel to the Pacific coast. Photographs are reproduced showing Atitlan and Santa Maria and also a nearer view of the new crater on the latter mountain; the distant view of Santa Maria is an exceptionally fine piece of work, and shows the great rent in the side of the cone and the new crater.

After several chapters dealing with Tarawera, Matavanu, and Kilauea, the book goes on to consider Java, Krakatau, and Luzon.

In Java Dr. Anderson visited, among other peaks, Guntur, Papandayang, Telaga Bodas, and the Tenger crater, with its enclosed cones of Batok, Bromo, and Widodaren. Guntur is a fine pyramidal mass rising up out of quite level ground. It is now quiescent, and, though a fine photograph of it was obtained from a distance, the jungle with which it was covered made it impossible to photograph the crater. Papandayang, which is quite close to Guntur, is also at present quiescent, but in 1772 there occurred one of the most destructive eruptions which have affected the island. It shows from a distance the characteristic form of a fragmental cone, its crater is large, but is now only occupied by fumaroles and hot springs. From here Dr. Anderson went on to the other end of the island, where he visited the Tenger crater and its accompanying smaller cones. This region shows volcanic phenomena on a very large scale. The Tenger crater, which is close to the town of Tosari, is 6 miles long by 4½ broad, and contains on its floor, which is known as the Zandzee, three minor cones, Batok, Bromo, and Widodaren. These all present the customary form of such minor fragmental cones, and their sides are deeply furrowed by small gullies cut out of the loose ash. Of these only Bromo is still active. Some very excellent photographs were obtained of this crater, one showing very well the smooth-sided depression like a "gigantic pudding mould" with the steaming vent at the bottom. From Java Dr. Anderson went on to Krakatau, and from there to Luzon in the Philippine Islands, where he visited the Taal lake and volcano, and also sailed round the island, taking photographs of several volcanoes on the way. One of these is Mayon, in the south-east corner of Luzon; this, as seen from the sea, presents a very fine example of an ash cone, being 8,970 feet high, quite symmetrical and showing the concave volcanic curve to perfection. This volcano was in eruption in 1814, and devastated the neighbouring country, killing 12,000 of the natives. At the south-western corner of the island is the Taal volcano. This is an island in the centre of the Taal or Bombon lake, which is a huge cauldron of water 17 miles long by 11 wide, and is probably the remains of a great caldera. The Taal volcano is about 760 feet high, dotted over with small craters, and having one chief crater about three-quarters of a mile wide; it contains two hot lakes and also a small internal crater with boiling mud on its floor. A few blocks of lava are visible, but no flows or dykes can be seen. There have been fairly frequent eruptions, the most violent of which took place in 1754.

The most striking feature of the photographs reproduced in this book is the many excellent distant views of the mountains which are included; the portraying of details of volcanic craters must always be difficult on account of the impossibility of exhibiting properly the bowl-like form from any position on the rim even with a lens giving a very wide angle of view, and also to the presence of clouds of smoke and steam, but the general view of a mountain is generally much more satisfactory from a pictorial and also scientific point of

view, and in this collection full advantage has been taken of this point by Dr. Anderson. However, the photographs of the craters of La Soufrière and Bromo are notable exceptions to the above statement and give the general form of these craters to perfection.

Unfortunately, Dr. Anderson never returned from his last journey to the East, as he was taken ill on his way home with enteric fever, from which he died and was buried at Suez. However, Professor Bonney is to be congratulated on giving to the world this collection of his photographs, which will be of the greatest service to all geologists and especially to those who are not so fortunate as to be able to go out and see the actual volcanoes themselves.

W. H. Wilcockson.

IV.—The Geology of the Moonta and Wallaroo Mining District, South Australia. By R. L. Jack. Geological Survey of South Australia. pp. 135, with figures, folding maps, and sections. Adelaide, 1917.

THE mines of the Moonta and Wallaroo area, on Spencer Gulf, are responsible for a very large proportion of the copper production of South Australia: up to the end of 1916 they had yielded copper to the aggregate value of over £19,000,000. This memoir gives a remarkably clear and well-written account of the geology of an area which is interesting both from its great economic importance and from its bearing on general petrological problems, and especially on the question of the differentiation of igneous magmas. The formations present are Precambrian, Cambrian, and Tertiary, together with a thick cover of recent deposits. The Precambrian series consists of highly altered sediments of various kinds, basic and acid igneous rocks, and a large mass of felspar-porphyry, which is probably intrusive in the foregoing: the whole of these are cut by granites and pegmatite dykes, also of Precambrian age. The productive lodes of the Moonta area are found in pegmatite dykes cutting the felspar-porphyry. They do not pass up into the Cambrian strata. The Cambrian rocks are not of much interest, and only a few small patches now remain. The Tertiary rock is a thin white or buff limestone, with fossils; the character of these is not stated in the report. A large part of the country is occupied by a so-called travertine of recent date: this is obviously similar to the surface limestones of South Africa. Along the coast and also in certain inland areas is an extensive development of sand-dunes.

The pegmatites of Moonta consist of quartz, microcline, and biotite, with a considerable number of peculiar minerals, especially hæmatite, tourmaline, ferberite, scheelite, molybdenite, galena, smaltite, blende, and apatite. By far the most important copper minerals are chalcopyrite and bornite. At the surface is an oxidized zone about 100 to 150 feet in depth, with a variety of oxides, sulphates, carbonates, and chlorides of copper and other metals. Below the leached caps of the lodes is a zone of native copper: this feature is difficult to explain. The lodes of the Wallaroo area are found in the ancient sediments, and are less well defined than those of Moonta,

being more in the nature of impregnations of the country rock, but the mineral assemblage is similar and is obviously derived from the same magma, perhaps at a slightly later date, when differentiation had proceeded further. At a still later stage there seems to have been a good deal of secondary enrichment by sulphides and chlorides.

This area forms an excellent example of the metasomatic type of vein deposit, including both sulphidic and oxidic ores. The connexion between the mineral veins and the granitic intrusions is particularly clear, and the mineral association is of a distinctive and peculiar character.

R. H. R.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *December* 5, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

A demonstration on the application of X-rays to the determination of the interior structure of microscopic fossils, particularly with reference to the dimorphism of the Nummulites, was given by E. Heron-Allen, F.L.S., F.G.S., Pres.R.M.S., and J. E. Barnard, F.R.M.S.

Mr. Heron-Allen said that in the year 1826 Alcide d'Orbigny published among the innumerable, and for many years unidentified, *nomina nuda* that compose his "Tableau Méthodique de la Classe Céphalopodes" the name *Rotalia dubia*. This species was left untouched by Parker & Jones in their remarkable series of articles "On the Nomenclature of the Foraminifera". The French naturalist G. Berthelin was the first investigator to unearth and make use of the "Planches inédites" which had been partly completed by d'Orbigny for the illustration of his great work upon the Foraminifera, a work that was never published. Working with Parker & Jones's paper, Berthelin made for his own use careful tracings of 246 of A. d'Orbigny's unfinished outline sketches. These sketches were never elaborated by d'Orbigny upon the "Planches", which are still preserved in the Laboratoire de Paléontologie under the care of Professor Marcellin Boule; among them was found the sketch of *Rotalia dubia*. On the death of Berthelin the tracings passed into the possession of Professor Carlo Fornasini, of Bologna, who reproduced them all in a valuable series of papers published between the years 1898 and 1908. Fornasini's opinion was that the organism depicted by d'Orbigny was doubtfully of Rhizopodal nature, and that it was probably referable to the Ostracoda. The speaker said that he had examined the d'Orbigny type-specimens in Paris in 1914, and had noted that *Rotalia dubia* was a worn and unidentified organism, resembling an Ostracod.

There the matter rested until Mr. Arthur Earland and the speaker, while examining the material brought by Dr. J. J. Simpson from the Kerimba Archipelago (Portuguese East Africa) in 1915, discovered one or two undoubted Foraminifera of an unknown type, which

resembled Berthelin's tracing. Professor Boule kindly sent the d'Orbigny type-specimen to London, and the Rhizopodal nature of *Rotalia dubia* was established. It is not a *Rotalia*, and it must await determination until more specimens are obtained. It has been named provisionally *Pegidia papillata*. There were two or three forms of the organism, but only one perfect specimen of the d'Orbigny type; and it was undesirable to risk destruction by cutting a section of it. In these circumstances Mr. Barnard was approached, and he experimented with the object of ascertaining the interior structure of the shell by means of the X-rays. His results were extraordinarily promising, and led to further experiments.

The speaker showed on the screen photographs of the common and dense Foraminifer *Massilina secans* (d'Orb.), followed by a skiagraph of the same. A skiagraph of the still denser test of *Biloculina bulloides*, d'Orb., shows the arrangement of the earlier chambers as clearly as it is indicated in Schlumberger's beautiful sections. The application of X-rays to the dense imperforate shells *Cornuspira foliacea* (Philippi) produced skiagraphs showing the dimorphism of the shells, both megalo- and microspheric primordial chambers being clearly distinguishable. Such results led to the extension of the experiments to the agglutinated arenaceous forms, of which sections are made with extreme difficulty. The skiagraph of *Astrorhiza arenaria*, Norman, shows the internal cavities that contained the protoplasmic body. Two arenaceous forms, *Botellina labyrinthica*, Brady, and *Jaculella obtusa*, Brady, that are almost identical in external appearance, are distinguished at once by their respective skiagraphs, the one exhibiting a simple tubular cavity, the other appearing labyrinthic.

Mr. Barnard subsequently experimented on still more difficult material. The massive *Operculina complanata*, Defrance, the umbilical portion of which is obscured by a mass of secondary shell-substance, furnished a clear skiagraph that showed some curious distortions of the internal septa. Similar results were obtained in the case of *Orbiculina adunca* (Fichtel & Moll), another species overladen with shell-matter. *Cyclammina cancellata*, Brady, is an arenaceous form, composed of softer mud and sand, studded with coarse sand-grains, which make section-cutting almost an impossibility. The skiagraphs, however, reveal the primordial chamber and establish the character of this form.

The determination of the Nummulites, depending as it does on a knowledge of the internal structure of the test, is greatly facilitated by the application of X-rays, which removes the necessity of splitting it or cutting sections through it.

The speaker showed ordinary photographs and skiagraphs, made at slightly varying azimuths, of *Nummulites lævigata* and *N. variolaria*, forms that strew the shores of Selsey Bill. A particularly notable result was obtained in the case of *N. gizehensis*, an organism that forms the dense masses of Nummulitic limestone of which the Pyramids of Egypt and the Citadel at Cairo are built.

Mr. Barnard said that, although the utilization of X-rays to determine the internal structure of various bodies was well known,

he was not aware that the method had been successfully applied to small objects, such as Foraminifera. After he had begun his experiments he found that M. Pierre Goby had done some work in this direction in France, but the method as he described it is surrounded with considerable mystery and elaboration of apparatus, which appear quite unnecessary. The speaker's results were arrived at independently; in fact, they are really a side issue.

His original experiments were directed rather towards the use of X-rays in obtaining magnified images, altogether apart from the usual skiagraphic methods in which a shadowgraph is, in fact, all that can be produced. The primary object has not yet been achieved, although there is some reason to hope that it may ultimately come to pass. The results shown by Mr. Heron-Allen are obtained by quite simple means. A very narrow beam of X-rays, such as would be termed "a parallel beam" when speaking in terms of ordinary light, is allowed to impinge on the object, the latter being in contact with the photographic plate. The negative produced is, therefore, of the same size as the object. Photographic enlargement is then resorted to, and the result had been shown on the screen. There are two points to which careful attention is required if success is to be achieved.

The quality of the X-rays must be suited to the object. In nearly all cases of small objects, what are known as "soft" X-rays must be used, and the degree of softness is the crux of the whole matter. The photographic plate must be of exceedingly fine grain, otherwise the amount of enlargement that can be obtained is very limited. Difficulties in this direction have been overcome, and Mr. Heron-Allen has stated that the results are of considerable biological value.

Dr. A. Smith Woodward, F.R.S., V.P.G.S., exhibited a radiogram of the original slab of lithographic stone containing the skeleton of *Archæopteryx*, made for the British Museum by Dr. Robert Knox in 1916. It was evident that the penetrability of the fossil bones to the X-rays was the same as that of the surrounding matrix. The only portions of the skeleton visible in the radiogram were those more or less raised above the general surface of the slab. This result accorded with that obtained by Professor W. Branca when he similarly experimented with the Berlin specimen of *Archæopteryx*.

2. *December* 19, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read:—

"The Chellaston Gypsum-Breccia considered in its relation to the Gypsum-Anhydrite Deposits of Britain." By Bernard Smith, M.A., F.G.S.

This communication is designed to clear up some of the ambiguities that have arisen with regard to the actual mode of formation of the deposits of gypsum in Britain—chiefly from the point of view of the field observer. An attempt is made also to show the true

relationship of the gypsum to the beds of anhydrite with which it is sometimes associated.

A description is given of a remarkable breccia occurring at Chellaston in Derbyshire, and its origin is discussed. Important occurrences of gypsum in other parts of the country, as well as the alternative theories as to their mode of formation, are then reviewed in the light thus obtained.

The remainder of the paper deals mainly with the possible interchanges between anhydrite and gypsum. The place and the function of the fibrous form of gypsum are indicated, and a nomenclature is suggested for certain isolated masses of the mineral.

The chief conclusions are as follows:—

1. At Chellaston the gypsum was laid down as such, and has suffered no appreciable alteration or addition since the time of its original deposition and brecciation. There is no evidence that the rock was ever anhydrous.

2. By comparison with this deposit, and also by independent evidence, it seems probable that most of the important beds of gypsum in the country were laid down as gypsum, and have behaved throughout as stratified deposits.

3. When anhydrite is present, the evidence favours the view that it is original, and was deposited in a stratiform manner in sequence with gypsum.

4. Microscopic evidence shows that there has been, in some cases, an alteration of anhydrite into gypsum where the two minerals were in original juxtaposition; this alteration, however, is considered to have occurred at, or immediately after, the time of deposition, and to be confined to the existing plane of contact of the two minerals.

II.—Edinburgh Geological Society.

December 19, 1917.—Professor Jehu, President, in the Chair.

1. "Marginal Intrusive Phenomena near Linlithgow and at Auchinoon." By T. Cuthbert Day, F.C.S., F.R.S.E. (Illustrated by lantern views and rock specimens.)

At Hillhouse Quarry, near Linlithgow, the dyke of white trap with its branches has produced considerable contact alteration in the limestones and shales, while the thick sheet of columnar olivine basalt which overlies the sediments does not appear to have caused any change; it, however, transgresses the strata considerably, which, it is suggested, may be due to contemporaneous erosion and that the basalt may prove to be a lava.

It was pointed out that the peculiar brecciation seen in certain bands of dolerite at Cockelrue which have been enclosed in the intrusive mass of the hill is probably due, not to crushing or movement, but to numerous crack joints produced on cooling.

The dolerites of the district do not readily take the form of white trap when found in contact with carbonaceous shales.

A large exposure of intrusion breccia was described in a quarry of

dolerite at Kettlestoun, composed of fragments of igneous and sedimentary rocks cemented together by dolerite, and occupying a large part of one face of the quarry. A peculiar spotted shale, due to contact alteration, in the same quarry was also described.

In connexion with the exposure of dolerite and overlying hornfels at Auchinoon, it was stated that a quantitative analysis of the alkalies in the dolerite showed a considerable falling off as the margin was approached, and that while the hornfels in contact showed nearly 7 per cent alkalies, no trace of lime was found in the specimen analysed.

2. "On a Section of the Wardie Shales, with Intrusions, exposed in the Stank at Corstorphine; and on the Draining of the Old Lochs at Gogar and Corstorphine." By D. Tait.

The main purpose of the communication was to record a hitherto unrecorded section of the Wardie Shales in the Stank at the west end of Dovecot Road, Corstorphine. The beds there consist of sandstone and shales, dipping west at 20°. These are cut by two east and west quartz dolerite dykes, which alter the shales in their vicinity. The section is on the south side of the Middleton Hall fault, the position of which is probably indicated by a spring of water situated a few yards north of the locality. It was pointed out that this section lies between Gogar Loch and Corstorphine Loch, both now drained, and also midway between the buried river channels of the Almond at Turnhouse and the Water of Leith at Roseburn. Both of these channels are below sea-level at these points. It therefore appears probable that the rocks in which this section was excavated formed a watershed between them in pre-Glacial times.

Photographs of a series of old maps, chronologically arranged, were thrown on the screen to show the progress of draining of Gogar Loch and Corstorphine Loch. An Act of Parliament shows us that these draining operations were in progress in 1661. Their final stage is recorded in the New Statistical Account, which says that about 1831 the Stank was widened and deepened.

III.—Mineralogical Society.

January 15, 1918.—W. Barlow, F.R.S., President, in the Chair.

Dr. J. W. Evans: "Diagrams expressing the Composition of a Rock." These diagrams are intended, like those of Michel Lévy and Mügge, to indicate at a glance the significance of the analysis of a rock or complex mineral silicate. The molecular proportions of the constituents are determined in the usual manner, those of the ferrous and magnesium oxides, however, being doubled. The silica is represented by two rectangles placed side by side, the length of each being half the molecular proportion of silica. In one of these rectangles lengths equal to the molecular proportions of potash, soda, and lime are measured off in succession, and in the other those of alumina, iron oxide, and magnesia. Thus, the same space represents both metallic oxide and silica, and so far as felspars, felspathoids, or ægirine are actually or potentially present, the monoxide and sesquioxide they contain are with two molecules of silica represented

by contiguous portions of the two rectangles. The excess, if any, of lime over available alumina has the silica necessary to form wollastonite, and the excess, if any, of iron oxide over available soda and the magnesia have the silica required to form orthosilicates. The remaining silica space is then divided up to show the additional silica required or available for the felspars, felspathoids, and ægirine, and that available to convert the orthosilicates of iron and magnesium into metasilicates. The remainder represents free silica or quartz.

Dr. G. F. Herbert Smith: "On the use of the Gnomonic Projection in the calculation of Crystals." If projected on to a plane at right angles to the edge of the zone containing the poles from which biangular measurements were made, the diagram takes the form of a net, the nodes of which represent the principal poles. The unit lengths of the net are easily calculated from the data, and once the rectangular co-ordinates of any node with respect to axes on the diagram have been determined those of the remainder follow by simple addition or subtraction; the corresponding spherical angles are deduced by a simple calculation. The accuracy of the calculations may be checked from the diagram at every step. To keep the projection corresponding to any crystal within reasonable dimensions it is sometimes convenient to project on to the faces of a cube. The direction of a zone when crossing from one face to another is very simply found from the diagram.

OBITUARY.

WILLIAM ALBERT PARKER, F.G.S.

BORN 1855. DIED JANUARY 14, 1918.

WE deeply regret to record the death of Mr. W. A. Parker, of Rochdale, which took place on January 14 at the age of 63. For many years he was a highly esteemed schoolmaster in Rochdale. Here he indulged his taste for scientific research, especially geology, and became associated in friendship with a small but enthusiastic body of geologists, including, amongst others, Walter Baldwin, the late W. H. Sutcliffe, Dr. March, James Horsfall, Robert Law, and S. S. Platt. Assisted by other members of this band Mr. Parker specially devoted himself to the task of working out the beds of shale, with ironstone nodules containing fossils, of Middle Coal-measure age at Sparth, Rochdale. This led to the discovery of a numerous and rich series of fossils, including rare Orthopterous insects, Arachnida, and Crustacea, many of which have been figured and described in the GEOLOGICAL MAGAZINE (see volumes for 1907, pp. 400–7, 539–49; 1911, pp. 361–6; 1913, pp. 352, 356). A new Crustacean, *Rochdaleia Parkeri*, was named after our friend. Many of these valuable specimens are now preserved in the Manchester Museum and in the British Museum (Natural History). His loss will be keenly felt by a large circle of geological friends in the Midlands.

H. W.